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PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

VOLUME I

MAY 1908 — FEBRUARY 1910

EDITED BY THE SECRETARY, PUBLISHED BY THE INTERNATIONAL ASSN. FOR TESTING MATERIALS, VIENNA 1910

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II.

PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

Published at irregular intervals in an English, French and German edition. For Members gratis.

VIENNA, May, 1908. Nr. 1.

Price of this number 6 d or 12 cents for non-Members. Publisher: E. & F. N. Spon Limited. London. 57 Haymarket.

Contents: Circular to Members as to the publication of the „Proceedings". Proceedings of the XVIIth Meeting of Council held in Munich 11th April 1908.

To the Members of the International Association for Testing Materials.

In consideration of the long-felt need of maintaining closer contact with the Members of the Association in the intervals between the Congresses, the Council have decided, at their last Meeting at Munich, to publish a periodical, appearing from time to time during the year, in consecutive numbers. This periodical will contain not only business communications, Congress papers and Congress proceedings, but also notices of the work published by the National Societies and the Laboratories for Testing Materials in the various countries; and further notices of any other prominent publications in this branch. By this last means the Council hope to offer the Members a slight, but useful addition to the index of professional literature published in the leading technical papers.

The Proceedings will appear in three independent editions, English, French and German and be sent gratis to the Members.

The Council trust that this innovation will not only contribute to strengthen the interest of Members in the International Association, but will also help to create new adherents.

Ernst Reitler,
General Secretary.

Alex. Foss,
President.

Minutes of Proceedings of the XVIIth Meeting of the Council

held in Munich, Hotel Continental, the 11th of April 1908.

The sitting was opened at 10 a. m.

Present: the Vice-presidents Messrs. A. Martens and N. Belelubsky,

Mr. F. Berger, Past-president,

the Members of Council:

Messrs. J. Benetti, Bologna,
L. Bienfait, Amsterdam,
B. H. Brough, London,
A. Greiner, Seraing,
H. I. Hannover, Copenhagen,
B. Kirsch, Vienna,
A. Mesnager, Paris,
F. Schüle, Zürich.

Further, accompanying Mr. Greiner: Mr. H. de Górski, Seraing,
the General-Secretary: Mr. E. Reitler, Vienna.

Mr. **Martens** opened the Meeting, welcomed those present, thanked them for their full attendance and informed them that the President had telegraphed with regret his inability to be present, owing to serious private affairs. On his motion, Dr. Berger was requested to take the chair.

Mr. **Berger** in the chair read letters of regret for non-appearance from Messrs.:

C. v. Banovits, Budapest, Castanheira das Neves, Lisbon, Ch. Dudley, Altoona, A. Granfelt, Helsingfors, S. A. Lund, Kristiania, Marvà y Mayer, Madrid, C. M. Mironesco, Bucharest, A. Milasinovic, Belgrad.

The **President** announced the unexpected and much regretted decease of Mr. E. Roussel, the highly appreciated director of the Laboratory at Malines, to whom the Association has been so much indebted for his self sacrificing labours as chairman of Section *C* of the last Congress; secondly the much regretted decease of Prof. R. Gießler, who had earned so much gratitude by his 12 years editorship of the Baumaterialienkunde, the only Journal for Testing Materials. Letters of sympathy in the name of the Council were dispatched to the families and to the editor's office.

A letter of congratulation had been sent to the Vice-president his Exc. Prof. N. Belelubsky in recognition of his forty years jubilee of public service and his receiving his honorary doctor's degree at the Technical College in Charlottenburg.

Two letters were read containing the following: that the Austrian experts under the chairmanship of Prof. Kirsch, and the Italian ditto under that of Prof. Benetti have constituted themselves National Societies, which have developed considerable activity, and are heartily congratulated by the Council.

1. Passing the minutes of XVIth Meeting of Council.

The printed minutes were unanimously approved.

2. Report on the work done by the Central office during past year.

The resolutions passed by the XVIth meeting of the Council have been carried into effect, and will be referred to singly in the agenda. The paper on the methods of testing recommended by the IVth congress had been put into the hands of three publishers: the English edition E. & F. N. Spon, Ltd., London and Spon & Chamberlain New York, the French ditto H. Dunod & E. Pinat, Paris, the German F. Deuticke, Leipzig and Vienna. Advertisement sheets were attached to this pamphlet, bringing in a fair sum.

3. Fluctuation in the number of members.

The present number of members in the varions countries are as follows:

Argentine	1		1077
Australia	11	Italy	55
Austria	177	Japan	1
Belgium	82	Luxemburg	3
Brasil	2	Norway	44
Chile	1	Portugal	14
Denmark	66	Roumania	21
Finland	28	Russia	200
France	170	Servia	3
Germany	350	Sweden	52
Great Britain	76	Switzerland	72
Holland	41	Spain	27
Hungary	72	United States of America	257
	1077	Total	1826

As can be seen, the Association received a substantial increase of Members in Great Britain, Belgium and Denmark.

In view of the many alterations to be made, a supplementary members list was not published, though a resolution for this had been passed in the XVIth Council's Meeting; it appeared advisable to publish a new list dating from 1st January 1909.

The technical Society "Den tekniske Forening" has joined the Association with a subvention of 25 K; the American Society has sent a subvention of 100 frcs.

A letter from Prof. Marburg, Secr. Am. Soc. T. Mat. was read, saying that the Executive Committee regretted that their efforts to stimulate interest in the International Association had not resulted in a larger membership in America. They congratulated the Association on the results of the last Congress, especially on its publications.

On the motion of Mr. **Greiner** the Council decided to request Mr. Bian, Directeur des Forges d'Eich de Dommeldange kindly to undertake the function of a Mandatary for Luxemburg.

4. Financial report.

The **General-Secretary** laid the following report before the Council.

Receipts and Expenditure of the Head Cash office.

Receipts	Amount detailed (Francs)	Amount total (Francs)	Budget
Supplement for 1906:			
Balance on 1906		1696·27	1696·27
Members' subscriptions received from Delegates	581·79		540·—
Interest	53·70		
Sale of Congresspapers	75·—	710·49	
		2406·76	
For 1907:			
Members' subscriptions received from Delegates			
Members' subscriptions and subvention from following countries received direct:	13627·84		13700·—
Japan 7.56			
Luxenburg 15·12			
Italy 7·50			
United States America 7·56			
Brasil 31·—			
Sweden 137·79	206·53		
Interest	46·37		120·—
Receipts from sale of Congress papers	555·25		—
Receipts from the advertisement sheets attached to the paper "Methods of testing"	1206·30		—
Subvention of the Brussels Organisation Committee	3500·—		3500·—
Sundries	13·12	19155·41	
Total		21562·17	

Expenditure	Amount detailed (Francs)	Amount total (Francs)	Budget
Supplement for 1906:			
Salaries	155·40		155·40
Postage	39·34		84·—
Office printing expenses	674·72		735·—
Congress Expenses: Translations	105·—		—
Remuneration	1200·—		1200·—
Sundries	31·33	2205·79	53·70
For 1907:			
Salaries and Stationery	7491·18		7560·—
Office printing expenses (Proceedings of Councils' Meetings, By-Laws, Members' tickets, circular)	1252·44		1459·50
List of problems and list of members	—		735·—
Postage	228·28		630·—
Office fittings (type writing machine)	498·75		840·—
Sundries (Losses on rates of exchange, administration of funds)	270·60		210·—
Committees	—		210·—
Congress Expenses:			
Printing expenses and postage	6231·64*)		7765·80
Translations	1762·22	17735·11	1260·—
Balance		1621·27	
Total		21562.17	

Receipts and Expenditure of the Members of Council and Mandataries for the year 1906.

Country	Balance on 1st January 1906	Sub-scriptions and Sub-ventions received	Total	Paid into Head cash office	Expendi-ture	Cash in hand on 1s January 1907
Supplement for 1906						
	Francs					
Italy	15·—	367·50	382·50	240·—	140·40	2·10
Sweden	21·25	390·—	411·25	341·79	69·46	—
Russia	—	1.568·30	1.568·30	1.289·40	278·90	—
Hungary	—	567·—	567·—	497·70	80·69	— 11·39
For 1907						
	Francs					
Australia	—	45·28	45·28	45·28	—	—
Belgium	—	615·—	615·—	581.50	33·50	—
Denmark	— 40·78	495·53	454·75	375·86	35·46	43·43
Germany	553·63	4.234·12	4.787·75	3.625·—	655·13	507·62
Great Britain	—	795·—	795·—	745·—	50·—	—
Finland	—	210·—	210·—	210·—	13·70	— 13·70
France	88.55†)	1.267·50	1.356·05	1 177·30	178·75	—
Holland	11·95	309·96	321·91	195·93	54·16	71·82
Italy	2·10	442·50	444·60	352·50	55·—	37·10
Norway	89·39	331·66	421·05	277·77	57·50	85·78
Austria	24·13	2.451·68	2.475·81	1.785·—	426·40	264·41
Portugal	2·70	105·—	107·70	97·50	9·85	0·35
Roumania *)	— 5.—	—	— 5.—	—	—	— 5·—
Russia *)	—	735·—	735·—	735·—	—	—
Sweden	—	390·—	390·—	390·—	—	—
Switzerland	3.40	671·20	674·60	525·—	112·17	37·43
Servia	—	22·50	22·50	20·25	2·25	—
Spain	—	187·50	187·50	187·50	—	—
Hungary	— 11·39	596·82	585·43	537·60	33·79	14·04
United States of America	—	2.109·62	2.109·62	1.763·85	345·77	—
Total	718·68	16.015·87	16.734 55	13.627·84	2.063·43	1043 28

*) The accounts for 1907 have not yet been presented.

†) Balance corrected.

The accounts differed from the budget in the following items.

The receipts were increased, through the unlooked for advertisement sheets in the Methods of Testing and through the sale of non official papers, by	1761.55	frcs.
On the other hand the expenses for printing, forwarding and translation of the Congress papers were higher than had been expected by	568.—	„
The actual expenditure for the printing of the general management came to a smaller sum, on account of the non-printing of the list of problems and supplementary list of members, by	942.06	„
Postage and purchase of a typewriter cost less than calculated by	742.97	„
The accounts for 1907 then concluded with a balance in hand of	1621.27	„
while bill	1600.—	„

for printing of Congress papers was not yet settled.

The report was taken note of, and Messrs. Schüle and Bienfait were requested to audit the books in hand by the afternoon.

5. Re the question of dealing with technical problems.

a) Report on the constitution of the committees nominated in the XVI[th] Meeting of Council.

Thanks to the willingness of the gentlemen invited, the Commissions nominated at the XVI[th] Meeting of Council have been constituted in the following way.

Commission 38 (Principles for specification of copper):

Chairman: Mr. Léon Guillet, Ingénieur en Chef de Service chimiques de la Maison de Dion-Bouton; 17 Avenue Carnot, Paris, XVIIIe.

Members: Messrs. C. Heckmann, Duisburg-Hochfeld.

G. Selve, Geh. Kommerzienrat, Altena i. W.

Dr. R. T. Glazebrook, Director of the National Physical Laboratory, Teddington.

F. Tomlinson, The Broughton Copper Comp. Ltd., Manchester (England).

G. Guillemin, Ingénieur-Conseil, Paris, Ve, Rue du Sommerard.

Breuil, Chef de la section des essais de métaux au Laboratoire des Arts et Métiers, Paris, 292 Rue St. Martin.

Olgouine, Ingénieur au Laboratoire méc. à l'école Imp. des ingénieurs des voies de communication, Moscou.

E. Wehrenpfennig, Zentralinspektor der österr. Nordwestbahn, Wien.

Zugmayer jun., Kupferfabrikant, Waldegg.

J. Gerwer, Oberingenieur des Schweizer elektrotechnischen Vereines.

G. E. Skinner, Electrical Engineer, Westinghouse Electrical Manufacturing Comp., East Pittsbburgh, Pa. (U. S. A.)

H. E. Diller, of the Hawthorne Engineering Laboratory, Western Elect. Comp., Chicago (U. S. A.).

Commission 39 (Principles of specifications of oil for technical purposes).

Chairman: Mr. Dr. Max Albrecht, Hamburg.

Vice-Chairman: Mr. E Camerman, Ingénieur en Chef au Laboratoire de l'Arsenal de l'Etat, Malines.

Members: Messrs. A. Jakobsen, Ingenieur, Chemiker der kgl. Dänischen Staatseisenbahn, Kopenhagen B.

Dr. Holde. Professor, Gr.-Lichterfelde

Havald Buch, Ingenieur der Norweg. Staatseisenbahnen, Christiana.

Dr. R. T. Glazebrook, Director of the National Physical Laboratory, Teddington.

Breuil, Chef de Section des essais de métaux au Laboratoire du Conservatoire des Arts et Métiers, Paris, 292 Rue St. Martin.

H. Baucke, Ingenieur, Amsterdam, Da Costakade 104.

H. Cattaneo, Aide du Directeur de l'Institut expérimental des chem. de fer de l'Etat, Rome.

Josef Großmann, Oberinspektor der österr. Nordwestbahn, Wien.

R. Kind, Mitchef der Firma Kind & Herglotz, Aussig a. E.

Gebrüder Sulzer, Maschinenfabrik, Winterthur.

A. H. Gill, Professor of the Massachusetts Institute of Technology, Boston.

H. A. Julius, Engineer for Designs and Tests, Gov. Railways, Western Australia, Railway Dep., Midland Junction, Western Australia.

Messrs. Gary and Feret have kindly consented to undertake the report on problem 40 (Unification of specification of gypsum).

Re Commission 41 (Concrete iron) under the Chairmanship of Mr. Considère, all gentlemen nominated in the last Meeting have consented to take part, with the exception of the Budapest Professors Nagy and Pecz, in the place of the former of whom Prof. A. Czako has joined the Committee. Besides the two gentlemen nominated in the XVIth Meeting, Russia has delegated Prof. Jitkewitsch, Messrs. Boguslawsky and Abramoff.

Re Commission 42 (Tests of hydraulic cements by prisms and determination of standard sand) all Laboratories named at the XVIth Meeting except those of Stockholm, Teddington (London) and Moscow have kindly given their consent. The last named Laboratory pointed out that they preferred working in metal tests and are ready to collaborate in this direction. This offer was accepted with thanks and they were referred to the respective principal questions to be dealt with.

Commission 30 (Separation of the finest particles in Portland cement) has been constituted according to the suggestion of the XVIth Meeting; only Mr. R. Dyckerhoff has had his place taken by his son Dr. A. Dyckerhoff.

b) Letters from the Chairmen of the Commissions.

The Chairmen of Commissions 2, 25, 7, 9, 11, 32, 33, 24, 34, were invited to resume their labours.

The following letters were noted:

Prof. **Howe,** chairman of the committee 24 for settling uniform nomenclature of iron and steel, requested the consent of the Council to add to the report in collaboration with Prof. Sauveur, a set of definitions of the microscopic constituents.

This proposal was gratefully accepted.

Re problem 18 (Paints for metals on metallic structures) a letter of Mr. Ebert was read, in which he declared his report

closed by his paper laid before the last Congress. It was decided: To request the American Society T. M. to nominate a gentleman to report before the next Congress upon the investigations made in America upon this point. Likewise to request the Royal Office for Testing Materials in Gr.-Lichterfelde to send a report, as well as Mr. Grittner of Budapest, the former coreferee.

Re Commission 34 (Definition and Nomenclature of bitumens) a letter of Prof. Lunge was read, expressing his opinion that his task had been finally concluded in the report laid before the last Congress and requesting to be allowed to resign his office as Chairman of the Commission. The Council decided to express their gratitude to Prof. Lunge for his labours and their regret at his resignation of office and to request him to kindly nominate for the next Congress a gentleman who would represent him in reading the report not dealt with at the last Congress.

Re Mr. **Rieppel's** subcommittee I (International specifications for testing and inspecting iron and steel) the **General Secretary** stated that the American Society in answer to the request of the Council had delegated Messrs. Wood and Webster for this subcommittee.

A letter from Mr. Rieppel was read in which he pointed out that to obtain real success for the work of the subcommittee, it was necessary first of all to make certain of the approval of the National Societies or leading bodies of those countries included in the work of the Commission. The following questions were therefore laid before the Council.

1. Is the work of the Subcommittee to be carried on under such an agreement with the national Societies for Testing Materials or with some similar Societies, that the results of the deliberations may be submitted to the sanction, or at least the judgement, of these Societies, or is the International Association, to decide for themselves on the propositions of the Subcommittee.

2. What course is to be followed especially in regard to Great Britain?

With regard to this question:

Mr. **Brough** stated that the British members of the Association had held a Meeting 1st April in which Mr. F. W. Harbord, a pro-

minent expert, had been unanimously confirmed as British representative on the Subcommittee I. and that they had recommended that the report of Committee I. should be submitted for the consideration of the Engineering Standards Committee and the Iron and Steel Institute.

After a long debate in which the Meeting agreed with the views of Mr. Rieppel, it was resolved to inform Mr. Rieppel of the position of the affairs in Great Britain through which the cooperation of leading British technical Societies would seem to be assured.

After Messrs. **Kirsch**, **Benetti** and **Belelubsky** had reported that Austria, Italy and Russia are on the point of unifying their specifications, and Mr. **Mesnager** had pointed out that in France the Government on one hand and the Railways on the other have each their own specifications, it was decided to draw the attention of Mr. Rieppel to this, with a view to these countries joining in time the work of the Commission.

The remaining reports laid before the last Congress but not dealt with, namely Probl. 7 (weathering resistance of building stones) 10 adhesive qualities of hydraulic cements, 11 (testing puzzolanas) are to be discussed at the next Congress.

c) Nomination of referees for the vacant Problems.

Re problem 28 (Magnetic and electric properties of metals in connection with their mechanical testing). Prof. **Kirsch** reported that work has been done in this department at the Technical College in Vienna. It was resolved to invite the Austrian Soc. T. M. to nominate a referee upon this question. Further, investigators from other countries as far as they shall be named by the Members of Council, shall be invited to kindly report.

A new edition of the List of Problems will be published in simplified form containing only name and dwelling-place of the committee members and referees.

6. Preparations for the next Congress:

Report upon the work of the Organising Committee:

Prof. **Hannover** reported that a large organising Committee composed of leading men from scientific, technical and manu-

facturing circles have already begun their work. The Ministers of the Home Department, of Communications and of War, the Presidents of both Houses, the Lord Mayor of Copenhagen, His Excellency Professor Thomsen, P. C., have kindly joined the Congress as Honorary Members and it is hoped that the King himself will graciously consent to be the leading Patron and the Crown-prince Honorary President. Very interesting excursions have been proposed in connection with the affair. In answer to a question of the Chairman, Prof. Hannover expressed the belief that the Organising Committee would vote the Association a sum for the printing of papers.

Prof. Hannover's report was taken grateful note of.

It was decided to fix the **date of the Congress for the beginning of September 1909**; but that invitations to the varions authorities should be sent out in the course of the next few months.

As final date for sending in reports the 1st January 1909 was decided on. The papers are to be sent to the Delegate of the respective country or direct to the General Secretary in Vienna.

The Council expressed the wish that the papers contributed might not exceed 8 printed octavo pages, the Council not being able to provide means for printing larger reports, in view of the great expense of editions in three languages.

7. Reports on the publication of a Journal.

The **General Secretary** reported that in conformity with the resolution passed in the XVIth Council's Meeting he had endeavoured to find ways and means for the publication of a Journal, which in short technical abstracts should give general information of all publications in all the technical departments in connection with the Association.

To reduce as far as possible the expenses of the enterprise, and to make sure on the other hand of the collaboration of the various countries, he had approached the Council Delegates and Mandataries for information as to how far they would be willing to lend their assistance in the publication of such a Review. Most of the gentlemen have kindly consented to support the enterprise as far as possible by nominating experts in their own countries who would be willing to collaborate for comparatively

small fees; nevertheless there was serious anxiety both as regards the financial possibility of such an enterprise, and also as to its real needfulness considering that all the larger technical periodicals print abstract summaries of all other technical publications.

In order to ascertain the financial demands of such a publication, offers were requested from leading publishers, and since, meanwhile, the "Baumaterialienkunde" had stopped at the end of 1907 with the death of Prof. Gießler, two possibilities had to be considered for the eventual starting of a Review for the International Association: Either a quarterly publication containing short abstracts as above, or a monthly periodical of the same extent as the quarterly, containing besides leading articles, a review on practical engineering and an index of current literature. The publishers declared that owing to the great expense of such a trilingual periodical they could only undertake the matter on the basis of a financial guarantee on the part of the Association, which guarantee would come to 10 Marks per member in the former case, and 11 Marks in the latter.

Prof. **Mesnager** made the further statement that the editor of the periodical "Materiaux de Construction" had offered to forward this journal gratis to the French speaking members of the Association at a cost of 10 Frcs. per member 96 quarto pages being placed at the disposal of the Association for their own communications.

These reports taken note of, and the sitting adjourned till three o'clock.

Reopening of the sitting at 3 p. m.

Continuation of the

Financial report and Priliminaries.

Prof. **Schüle** reported having audited the books together with Mr. Bienfait. The auditors declared themselves fully satisfied with the financial report for 1907. The settlement of accounts for 1907 was concluded with a balance of 1621·27 Frcs.

The receipts and expenses occurring since then left the balance in cash on 10th April at 2448·75 Frcs. which amount according to the voucher of the Allg. Depositenbank in Vienna was there lying to the credit of the Association. The discharge was accordingly given to the President.

In addition to this the following budget for 1908 was approved.

Budget of the Head Cash office for 1908.

Receipts	Frcs.	Expenditures	Frcs
Cash in hand	1.621·27	Payment in arrear for 1907	1.600·—
Members subscription (Supplement for 1907) .	80·—	Salaries and Stationery .	7.560 —
Member's subscriptions and subvention for 1908 .	13.900 —	Office printing expenses .	1.100·—
Interests	50·—	Postage	800·—
Receipts from sale of Congress papers	100 —	Sundries	200·—
		Congress expenses	1.000·—
		Balance	3.891·27
Total . . .	15.751·27	Total . . .	15.751·27

7. Continuation of the debate on the

Publication of a Journal.

After a long debate it was decided in view of the heavy expenses to drop the idea of publishing periodicals as above. On the other hand trilingual "**Proceedings of the International Association**" should be published from now onwards in occasional numbers and consecutive series and be forwarded gratis to the members.

These Proceedings should contain:

1. All business and official information of the Association.

2. The technical reports as Congress papers and Congress minutes.

3. An index, beginning from the IV^th^ Brussels Congress — September 1906 —

a) of those works published by the National Societies,

b) of those published by the Laboratories of the different states,

c) and of those technical articles from various periodicals which the Council members point out as worthy of notice especially regarding the results of practical experiment

and experience. This index shall give the titles, in conection with indications of the scope of the contents, in all three cases, and the respective sources of the articles.

By means of these last measures the Council hope to maintain contact among the members in the time between the Congresses; and to offer them a valuable supplement to the Reviews already appearing in larger journals on the publications in Material Testing.

It was left to the General Secretary to find a publisher to put the Proceedings on the market and to provide them with advertisement sheets.

8. Motions.

Prof. **Belelubsky** pointed out how important the question of painting building stones with flourines compounds had become and how valuable it would be to receive a reliable report on the success of those processes used in various countries.

Mr. **Bienfait** moved the discussion at the Congress of the question how far the concrete iron is affected by the electrolytical influence of water underground.

The Council decided as to both proposals to leave it to the experts to report on these points in reference to the principal questions to be discussed on the weathering of stones and the concrete iron.

On the motion of the Chairman the length of notice in the contract with the General Secretary was increased from three months to 12. Only in case of permanent inability on the part of the Secretary the quarterly notice should hold good.

It was resolved to hold the next Meeting of the Council on the first Saturday of February 1909 in Frankfort-on-Main.

After Mr. **Brough** had proposed a vote of thanks to Mr. Berger for the excellent way in which he had conducted the Proceedings, the Meeting was closed 5 p. m.

E. Reitler,
Secretary.

F. Berger,
Chairman.

INTERNATIONAL ASSOCIATION
□□ FOR TESTING MATERIALS □□

General Secretary's Office: Vienna, Austria, II/2, Nordbahnstraße 50.

Membership.

The annual subscription for each member is at least 6 s or 1.50 $.

Those wishing to join the International Association should apply:

for GREAT BRITAIN, to Mr. Bennett H. Brough, General Secretary of The Iron and Steel Institute, London.
„ THE UNITED STATES OF AMERICA, to Prof. Edgar Marburg, Secretary of the Am. Soc. Test. Mat., Philadelphia.
„ AUSTRALIA, to Prof. W. H. Warren, University of Sydney.

Papers of the IVth Congress, held at Brussels 1906.

These can be obtained from the General Secretary at the rate of 0.25—1 K each. The Minutes of the Congress Proceedings 2 K a copy. (1 K = 10 d = 20 cents.)

Obtainable at all booksellers:

"Methods of Testing metals and alloys; hydraulic cements and woods; clay, stoneware; and cement pipes", recommended by the IVth Congress. E. & F. N. Spon Ltd., London. Spon & Chamberlain, New York. (Price 1 s.)

□□ Edited by the International Association for Testing Materials. □□
Printed by Paul Gerin, Vienna.

PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

Published at irregular intervals in an English, French and German edition. For Members gratis.

VIENNA, May, 1908. Nr. 2.

Price of this number 6 d or 12 cents for non-Members. Publisher: E. & F. N. Spon Limited. London. 57 Haymarket.

Contents:

Notice.

The Vth Congress will be held at the beginning of September 1909 in Copenhagen.

The Principal Questions to be first of all discussed at this Congress are noted on the next page.

Papers dealing with these Principal Questions should be sent in to the respective Member of Council or to the General Secretary, Vienna (Austria) II Nordbahnstraße 50 not later than 1st January 1909.

Such papers should if possible not exceed 8 octavo printed pages, the Council not being able to print longer papers in view of the very heavy expenses of publication in three languages.

The reports of Commissions and Referees nominated for technical problems — noted further on — should likewise be sent in not later than the 1st January 1909.

In order to give a correct idea of the general drift of all papers, the authors are urgently requested to attach a short abstract of the same, which will form the basis of discussions at the Congress.

I.

Principal Questions

to be first of all discussed at the Vth Congress at Copenhagen 1909.

A. Metals:

a) Metallography,
b) Hardness testing,
c) Impact tests,
d) Testing metals by alternating stresses, thermal treatment etc.
e) Testing of cast iron,
f) Influence of increased temperature on the quality of metal.

B. Hydraulic Cements:

g) Reinforced concrete,
h) Progress in the Methods of testing,
i) Cement in sea-water,
j) Constancy of volume,
k) Tests by means of prisms and standard sand,
l) Weathering resistance of building stones.

C. Miscellaneous:

m) Oils,
n) Caoutchouc,
o) Wood,
p) Paints on metallic structures.

II.

List of technical problems,

committees and referees.

(The exact adresses are to be found in the Members List.)

Problem 1.

On the basis of existing specifications to seek methods and means for the introduction of international specifications for testing and inspecting iron and steel of all kinds. (Proposed at the Zurich Congress 1895. Enlarged at the Budapest Congress 1901.)

Chairman of the Commission: Dr. A. Rieppel, Nuremberg.

Vice-Chairman: G. Alpherts, The Hague.

Members: W. H. Verhoop, Liege; F. Öllgaard, Copenhagen; A. Martens, Gr.-Lichterfelde; F. W. Harbord, London; W. C. Unwin, London; J. H. Wicksteed, Leeds; A. Bécard, Paris; L. Baclé, Paris; J. Schröder van der Kolk, The Hague; W. A. Verhoop, Liège; C. Guidi, Turin; E. Mayrisch, Düdelingen, Luxemburg; A. v. Dormus, Vienna; N. Belelubsky, St. Petersburg; N. B. Bogouslawsky, St. Petersburg; N. Chtchoukine, St. Petersburg; B. Herberz, St. Petersburg; B. Koslowsky, St. Petersburg; P. Babouroff, St. Petersburg; Gunnar Dillner, Stockholm; Ant. Schrafl, Lucerne; M. Cano y de Leon, Madrid; H. H. Campbell, Steelton, Penna,; J. Christie, Philadelphia, Pa.; Carnegie Steel Company Ltd. (Repr.: John Mc. Leod), Pittsburg; Franklin Institute (Repr.: Wm. H. Wahl), Philadelphia; P. Kreuzpointner, Altoona; R. Moldenke, New York; W. R. Webster, Philadelphia; Walter Wood, Philadelphia.

Problem 2.

To establish methods of inspection and testing for determining the uniformity of individual shipments of iron and steel and to study how the ball pressure tests can be used for piece tests. (Proposed at the Stockholm Congress 1897. Enlarged at the Brussels Congress 1906.)

Chairman of the Commission: Ast, Vienna.

Members: H. I. Hannover, Copenhagen; F. Böcking, Düsseldorf; A. Martens, Gr.-Lichterfelde, K. Lutz, Munich; H. Otto, Essen a. d. Ruhr; A. Riepel, Nuremberg; Sugg, Königshütte, Oberschlesien; R. A. Hadfield, Sheffield; J. E. Stead, Middlesborough; H. R. J. Burstall. London; E. W. Monkhouse, London; W. C. Unwin, London; J. Cohade, Le Creusot; E. Le Blant, Paris; A. Pourcel, Paris; A. Sauvage, Paris; L. Bienfait, Amsterdam; St. Fadda, Turin; C. Guidi, Turin; Technical College of Trondhjem, Trondhjem (Norway); B. Kirsch, Vienna; A. Sailler, Vienna; F. Baerlin, Lisbonne; N. Belelubsky, St. Petersburg; J. Drouginine, St Petersburg; Fürst A. Gagarine, St. Petersburg; M. Guédéonoff, Kiev; A. de Jechotarsky, St. Petersburg; A. von Julin, Fiskars (Finland); Rud. Kolster, Helsingfors; N. Lamine, St. Petersburg; J. A. Brinell, Stockholm; B. H. Wallin, Gothenburg; Materialprüfungs-Anstalt am eidgen. Polytechnikum (Laboratory for Testing Materials), Zurich; Klerits, Belgrad; Lorenzo de la Tejera, Madrid; C. v. Banovits, Budapest; S. Rejtö, Budapest; J. Seefehlner, Budapest; Booth, Garrett & Blair, Philadelphia; Th. Gray, Terre Haute, Ind.; C. Gus. Henning, New York; P. Kreuzpointner, Altoona, Pa.; A. A. Stevenson, Burnham, Pa.; W. R. Webster, Philadelphia; A. Sauveur, Boston, Mass.

Problem 4.

Methods for testing welds and weldability. (Proposed at the Zurich Congress 1895.)

No special referee nominated.

Problem 6.

On the most practical methods of polishing and etching for the macroscopic study of iron and steel. (Proposed at the Zurich Congress 1895.)

No special referee nominated.

Problem 25.

To establish uniform methods of testing cast iron and finished castings. (Proposed at the Budapest Congress 1901.)

Chairman of the Commission: R. Moldenke, New York.

Members: Doat, Liège; Fr. A. Krogh, Copenhagen; C. Jüngst, Charlottenburg; H. Joly, Wittenberg; Wüst, Duisburg; J. E. Stead, Middlesborough; G. Charpy, Montluçon (Allier); J. Muysken, Amsterdam; S. Fadda, Turin; N. C. Ihlen, Strömmen per Christiania; H. Freiherr v. Jüptner, Vienna; Edgar v. Lenz, Traisen (N.-Österreich); Bureau des forges, St. Petersburg; A. Sulzer-Großmann, Winterthur; Al. E. Outerbridge Jr., Philadelphia; Alb. Sauveur, Boston, Mass.; Th. D. West, Sharpsville, Pa.

Problem 26.

Tests with notched bars for ascertaining the relations between the different methods of testing and for fixing the numerical values representing the different properties of metals. (Proposed at the Budapest Congress 1901.)

No special referee nominated.

Problem 27.

Ball-pressure tests for ascertaining the relations between the different methods of testing and for fixing the numerical representing the different properties of metals. (Proposed at the Budapest Congress 1901.)

No special referee nominated.

Problem 28.

The consideration of the magnetic and electric properties of materials in connection with their mechanical testing. (Proposed at the Budapest Congress 1901.)

At the time of this List going to press referees had not yet been nominated.

Problem 36.

On macroscopic examination of iron. (Drawn up by the XIth Council Meeting 1903.)

No special referee nominated.

Problem 37.

On microscopic examination of iron. (Drawn up by the XI[th] Council Meeting 1903.)

No special referee nominated.

Problem 38.

The principles for specifications of copper are to be studied. (Proposed at the Brussels Congress 1906.)

Chairman of the Commission: Léon Guillet, Paris.

Members: C. Heckmann, Duisburg-Hochfeld; G. Selve, Altena i. W. (Germany); R. T. Glazebrook, Teddington near London; F. Tomlinson, Manchester; G. Guillemin, Paris; P. Breuil, Paris; Olgouine, Moscou; E. Wehrenpfennig, Vienna, Zugmayer jun., Waldegg (N.-Österreich); J. Gerwer, Zurich; G. E. Skinner, East Pittsburg; H. E. Diller, Chicago.

Problem 43.

What effect upon the quality of the metal was produced during the forging, hammering, and rolling of ingot iron and steel by I. the temperature of the metal *a)* at the beginning of the operation, *b)* at the end of the operation; II. the amount of energy impressed upon it, e. g. the alteration in dimensions thereby produced. (Resolution of the XVI[th] Council Meeting 1907.)

No special referee nominated.

B. Hydraulic cements:

Problem 7.

On the relation of chemical composition to the weathering qualities of building stones. Influence of smoke, especially sulphurous acid on building stones. — On the weathering qualities of roofing slates. (Proposed at the Zurich Congress 1895.)

Chairman of the Commission: A. Hanisch, Vienna.

Vice-Chairman: P. Larivière, Paris.

Members: E. Dietrich, Berlin; E. Glinzer, Hamburg; H. Seipp, Kattowitz; A. B. W. Kennedy, London; A. Siemens, London;

H. L. J. Vogt, Christiania; A. Greil, Vienna; N. Kournakoff, St. Petersburg; N. Lamine, St. Petersburg; J. Maluga, St. Petersburg; Perrimonde, St. Petersburg; A. Wikander, Göteborg (Sweden); H. Brunner, Lausanne (Switzerland); Grubenmann, Zurich; G. Lunge, Zurich; V. Wartha, Budapest; J. F. Kemp, New York; M. Merrimann, South Bethlehem (Pa.).

Problem 9.

On rapid methods for determining the strength of hydraulic cements. (Proposed at the Zurich Congress 1895.)

Chairman of the Commission: F. Berger, Vienna.

Members: E. Camerman, Brussels; D. Berg, Aalborg (Denmark); C. Heintzel, Luneburg (Germany); W. Michaëlis, Berlin; F. Schott, Heidelberg; J. A. Ewing, Cambridge; E. Candlot, Paris; A. Mesnager, Paris; R. Feret, Boulogne s/M.; L. Bienfait, Amsterdam; Morris, Christiania; A. Greil, Vienna; T. Behrmann, Riga (Finnland); N. Belelubsky, St. Petersburg; N. Bogdanoff, St. Petersburg; L. Proskuriakoff, Moscow; T. Schilling, Moscow; A. Wikander, Göteborg (Sweden); D. v. Nagy, Budapest; W. W. Maclay, Glens Falls, N. Y.; Ch. F. Mc Kenna, New York.

Problem 10.

To digest and evaluate the resolutions of the conferences of 1884—1893, concerning the adhesive qualities of hydraulic cements. (Proposed at the Zurich Congress 1895.)

Referee: R. Feret, Boulogne s/M.

Problem 11.

To establish methods for testing puzzolanas with the object of determining their value for mortars. (Proposed at the Zurich Congress 1895.)

Chairman of the Commission: G. Herfeldt, Andernach.

Vice-Chairman: C. Segré, Ancona.

Members: E. Camerman, Brussels; C. van Bogaert, Antwerp; M. Gary, Gr.-Lichterfelde; W. Michaëlis, Berlin; P. Wagner, Cologne; A. Mesnager, Paris; R Feret, Boulogne s/M.; A. P. M. Kaptein, Utrecht (Hollande); J. A. van der Kloes, Delft

(Hollande); A. Arlorio, Turin; S. Canevazzi, Bologne; C. Cattaneo, Ancona; Ceradini, Rome; G. Giorgis, Rome: C. Guidi, Turin; O. Rebuffat, Naples; A. Greil, Vienna; H. Hillinger, Vienna; N. Bogdanoff, St. Petersburg; F. Konossewitsch, St. Petersburg; A. Lundteigen, Union City (Mich.).

Problem 12.

Investigation on the behaviour of cements as to time of setting and on the best method for determining the beginning and the duration of the process of setting. (Proposed at the Zurich Congress 1895, enlarged in conformity with the resolution of the Budapest Congress 1901.)

No special referee nominated.

Problem 30.

Determination of the simplest method for the separation of the finest particles in Portland cement by liquid and air process. (Proposed at the Budapest Congress 1901.)

Chairman of the Commission: M. Gary, Gr.-Lichterfelde.

Members: A. Dyckerhoff, Biberich a. Rh.; Bamber, London; A. Mesnager, Paris; Lejeune, Le Teil (France); Mayntz-Petersen, Copenhagen; Eidgenössische Materialprüfungs-Anstalt (Laboratory for Testing Materials), Zurich.

Problem 31.

On the behaviour of cements in sea-water. (Proposed at the Budapest Congress.)

No special referee nominated.

Problem 32.

On accelerated tests of the constancy of volume of cements. (Decision of the Zurich Congress 1895.)

Chairman of the Commission; Bertram Blount, London.

Members; Hiertz, Seraing; Mayntz-Petersen, Copenhagen; Ferd. M. Meyer, Malstatt-Burbach b. Saarbrücken (Germany); F. Schott, Heidelberg; R. Curling-Styles, Kent; E. Leduc, Paris; L. Bienfait, Amsterdam; O. Rebuffat, Naples; O. Carlsen,

Christiania; A. Greil, Vienna; Th. Pierus, Vienna; A. Baykoff, St. Petersburg; O. Blaese, Port Kunda per Wesenburg (Russia); E. Schwarz, Noworossiisk (Russia); V. Tagnéef, St. Petersburg; Des. Nagy, Budapest; Jos. Zhuk, Budapest; Spencer B. Newberry, Sandusky (Ohio); Rob. W. Lesley, Philadelphia.

Problem 33.

On the influence of the proportion of water and sand on the strength of Roman and other cements. (Proposed at the Budapest Congress 1901.)

Referee: Hungarian Society for Testing Materials.

Problem 40.

Study of the unification of specifications for gypsum. (Proposed at the Brussels Congress 1906.)

Referees: Max Gary, Gr.-Lichterfelde; R. Feret, Boulogne-sur-Mer.

Problem 41.

Investigations of reinforced concrete. (Proposed at the Brussels Congress 1906.)

Chairman of the Commission; Vacant.*)
Vice-Chairmen: Schüle, Zurich;
Germelmann, Berlin.

Members: W. H. Warren, Sydney; Paul Christoph, Brussels; E. Suenson, Copenhagen; T. Grut, Copenhagen; Alf. Hüser, Oberkassel (Germany); E. Züblin, Straßburg i. E. (Germany); A. Martens, Gr.-Lichterfelde; Bürstenbinder, Hamburg; Edwin O. Sachs, London; Max Clarke, London; Rabut, Versailles; A. Mesnager, Paris; R. Feret, Boulogne; Tricon, Paris; S. J. Rutgers, Rotterdam; Silvio Canevazzi, Bologna; Camillo Guidi, Turin; Claudio Segré, Rome; R. Norwegien Road-Department in Christiania; J. Melan, Prague; B. Kirsch, Vienna; F. v. Emperger, Vienna; N. Belelubsky, St. Petersburg; Droujinine, St. Petersburg; Jitkewitsch, St. Petersburg; Boguslawsky,

*) At time of this List going to press Mr. Considère having just resigned his functions as chairman of the Commission.

St. Petersburg; Abramoff, St. Petersburg; F. Schüle, Zurich; R. Maillart, Zurich; Richard Zielinski (Szilard), Budapest; Josef Schustler, Budapest; A. Czako, Budapest; A. N. Talbot, Illinois.

Problem 42.

Uniform tests of hydraulic cements by prisms and determination of a standard sand. (Proposed at the Brussels Congress 1906.)

Chairman of the Commission: F. Schüle, Zurich.

Members: Laboratoire des Ponts et Chaussées, Boulogne s/M. (R. Feret); Laboratoire des Ponts et Chaussées, Paris (A. Mesnager, Mercier); Laboratoire du Conservatoire des Arts et Métiers, Paris (Leduc); Kgl. Material-Prüfungsamt, Gr.-Lichterfelde (A. Martens, M. Gary); Laboratorium des Vereines deutscher Portland-Zementfabrikanten, Karlshorst bei Berlin (Framm); Eidgenössische Material-Prüfungsanstalt, Zurich (Schüle); Laboratoire méc. de l'Institut Imp. des voies de comm., St. Petersburg (N. Belelubsky, Bogdansky); Mechanisch-technisches Laboratorium der technischen Hochschule, Wien (B. Kirsch); Dänische Staatsprüfungsanstalt in Copenhagen (Mayntz-Petersen); Ecole d'applications pour les Ingeniéurs, Bologna (S Canevazzi); Laboratoire de l'Arsenal de l'Etat Belge, Malines (E. Camerman); Material-Prüfungsanstalt von Bienfait & Koning, Amsterdam (L. Bienfait); Materials Testing Laboratory United States Geological Survey (L. Humphrey), St. Louis, Mo.

C. Sundries:

Problem 18.

On the methods of testing the protective power of paints used on metallic structures. (Proposed at the Zurich Congress 1895.)

Referee: At the time of this List going to press referees had not yet been nominated.

Problem 24.

On uniform nomenclature of iron and steel. (Resolution of Council, February 3rd 1901.)

Chairman of the Commission: M. Howe, New York.

Vice-Chairman: L. Lévy, Paris; D. Tschernoff, St. Petersburg.

Secretary of the Commission: Alb. Sauveur, Boston.

Members: Van Drunen, Ixelles; H. Truxen, Copenhagen; H. Wedding, Berlin; H. Brauns, Dortmund; E. P. Martin, South Wales; A. Pourcel, Paris; K. F. Koning, The Hague; P. Verole, Milan; A. Baalsrud, Christiania; A. R. v. Dormus, Vienna; A. Sailler, Vienna; Bureau des forges, St. Petersburg; Prof. N. Belelubsky, St. Petersburg; N. Jossa, St. Petersburg; M. Korobkoff, St. Petersburg; S. Smirnoff, St. Petersburg; H. H. Campbell, Steelton, Pa.

Problem 34.

Fixing a uniform definition and nomenclature of the bitumens. (Proposed at the Budapest Congress 1901.)

Chairman of the Commission: Vacant. Mr. Lunge having resigned his office.

Vice-Chairman: Jenö Kovács, Tataros (Mezö Telegd), (Hungary).

Members: M. Albrecht, Hamburg; Eger, Munich; D. Holde, Berlin; Locherer, Paris; Em. Potérno, Rome; L. Schmelk, Christiania; M. Böhm, M.-Ostrau (Austria); B. Kirsch, Vienna; A. Grittner, Budapest; A. W. Dow, Washington; Clifford Richardson, Long Island City, N. Y.

Problem 35.

Study of the methods of testing caoutchouc. (Proposed at the Budapest Congress 1901.)

Chairman of the Commission: E. Camerman, Brussels.

Members: Engelbert, Liege; A. Jacobsen, Copenhagen; Eger, Munich; P. Breuil, Paris; G. B. Pirelli, Milan; E. Simonsen, Christiania; A. R. v. Boschan, Vienna; B. Kirsch, Vienna; B. Kempe, St. Petersburg; Fr. Maly, Budapest; R. G. Pearson, New York.

Problem 39.

Study of the principles of specifications of oil for technical purposes. (Proposed at the Brussels Congress 1906.)

Chairman of the Commission: M. Albrecht, Hamburg.

Vice-Chairman: E. Camerman, Malines (Belgium).

Members: A. Jakobsen, Copenhagen; Holde, Gr.-Lichterfelde; Havald Buch, Christiania; R. T. Glazebrook, Teddington near London; P. Breuil, Paris; H. Baucke, Amsterdam; H. Cattaneo, Rome; J. Großmann, Wien; R. Kind, Aussig a. E. (Austria); Gebrüder Sulzer, Winterthur; A. H. Gill, Boston; H. A. Julius, Midland Junction, Western Australia.

INTERNATIONAL ASSOCIATION □□ FOR TESTING MATERIALS □□

General Secretary's Office: Vienna, Austria, II/2, Nordbahnstraße 50.

Membership.

The annual subscription for each member is at least 6 s or 1.50 $.

Those wishing to join the International Association should apply:

for GREAT BRITAIN, to M. Bennett H. Brough, General Secretary of The Iron and Steel Institute, London.
„ THE UNITED STATES OF AMERICA, to Prof. Edgar Marburg, Secretary of the Am. Soc. Test. Mat., Philadelphia.
„ AUSTRALIA, to Prof. W. H. Warren, University of Sydney.

Papers of the IVth Congress,

held at Brussels 1906.

These can be obtained from the General Secretary at the rate of 0.25—1 K each. The Minutes of the Congress Proceedings 2 K a copy. (1 K = 10 d = 20 cents.)

Obtainable at all booksellers:

„Methods of Testing metals and alloys, hydraulic cements and woods, clay, stoneware and cement pipes", recommended by the IVth Congress E. & F. N. Spon Ltd., London. Spon & Chamberlain, New York. (Price 1 s.)

□□ Edited by the International Association for Testing Materials. □□
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PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

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Contents: Bennett H. Brough †. — Official Communications. — Index of literature: I Standard prescriptions. II Periodicals. III New Books.

Bennett H. Brough †.

The International Association have suffered a severe loss in the death of Mr. Bennett H. Brough, Secretary of the Iron and Steel Institute, Delegate for Great Britain in the Council of the Association. He died October 3rd at Newcastle on Tyne.

Throughout the two years during which he was actively engaged in his work as Council's Member, Mr. Brough continued to promote the interests of the Association with the utmost energy and success.

The Association will always hold his name in grateful respect and remembrance.

Mr. J. P. Sidney, Assistant Secretary of the Iron and Steel Institute has kindly undertaken to carry on the business of Council's Member until the election of a new Delegate for Great Britain shall be completed.

The Vth Congress at Copenhagen.

The Organisation Committee of the Vth Congress have decided to hold the Meetings in Copenhagen from 7th until 11th September 1909. These Meetings will be followed by technical excursions.

Changes in the Commissions.

(See Proceedings No. 2.)

Problem 1 (International standard specifications for iron and steel):

Mr. F. E. Robertson, M. Inst. C E., London, joined.

Problem 2 (Homogeinity of iron and steel):

Mr. W. Ast, Chairman. resigned on account of health.

Problem 38 (Specifications for copper):

Prof. R. v. Stockert, Vienna, joined.

Mr. J. Gerwer, Zurich, resigned.

Problem 41 (Iron concrete):

Prof. F. Schüle, Zurich, Chairman, *vice* Mr. Considère resigned, but remaining in the Commission as member.

Prof. A. N. Talbot, Urbana, Ill., new Vice-Chairman.

New members: Mr. V. Brausewetter, Vienna, Prof. E. Turneaure, Madison, Wis.

Problem 24 (Nomenclature of iron and steel):

New members: Prof. H. Le Chatelier, Paris, Mr. F. Osmond, Paris, Prof. W. Campbell, New York

As regards the insertion of advertisements in this paper, see last page.

Notice: Messrs. W. Ernst & Sohn, Berlin, the publisher of the German book on the resistance of stones entitled: Die Prüfung der natürlichen Bausteine auf ihre Wetterbeständigkeit“ von Prof. Dr. J. Hirschwald, 36 M., offer the same to members of the International Association at the reduced price of 25 M.

Annex to "Proceedings" No. 3.

December 1908.

Principal Questions

to be first of all discussed at the Vth Congress at Copenhagen 1909 and the

official referees.

(The complete list of all official and non-official papers will be given in No 4.)

A. Metals:

a) **Metallography.** Prof. E. Heyn, Gr.-Lichterfelde W.
b) **Hardness testing.** Dr. P. Ludwik, Vienna.
c) **Impact tests.** Mr. G. Charpy, Montluçon.
d) **Testing metals by alternating stresses, thermal treatment etc.** Mr. E. J. Howard, Watertown, Mass.
e) **Testing of cast iron.** Dr. R. Moldenke, New York.
f) **Influence of increased temperature on the mech. qualities of metals.** Prof. M. Rudeloff, Gr.-Lichterfelde W.

B. Concrete, Hydraulic Cements, Stones:

g) **Reinforced concrete.** Prof. F. Schüle, Zürich.
h) **Progress in the Methods of testing.** Mr. R. Feret, Boulogne s. M.
i) **Cement in sea-water.** Prof. A Baykoff and Mr. W. Czarnomsky, St Petersburg.
j) **Constancy of volume.** Mr. B. Blount, London.
k) **Tests by means of prisms and standard sand.** Prof. F. Schüle, Zürich.
l) **Weathering resistance of building stones.** Prof. A Hanisch, Vienna.

C. Miscellaneous:

m) **Oils.** Dr. M. Albrecht, Hamburg.
n) **Caoutchouc.** Mr. E. Camerman, Brussels.
o) **Wood.** Mr. G. Pinchot, Forest Service, Washington.
p) **Paints on metallic structures.** Mr. S. S. Voorhees, Washington, and Prof. M. Rudeloff, Gr.-Lichterfelde W.

Index of Publications concerning Testing Materials.*)

In the following we begin a review of all the more important works relating to the domain of the testing of materials, which have been issued since the meeting of the last congress in September 1906. The large number of the publications obliges us to confine ourselves to the time reaching to the end of 1907. We shall follow these up as soon as possible with the publications of the year 1908.

Although this review may, in spite of all efforts, contain gaps, it may fairly claim for itself the advantage that it gives an account of the publications in the domain of the testing of materials in a comprehensive manner not attained by any of the excellent existing reviews with large means at command.

The most valuable feature of the review, however, does not appear to us to consist in its comprehensiveness, but much more in the attention drawn by it to the works of the national societies and laboratories all over the world, the titles of which in other publications are absent or difficult to find.

In this direction we wish to attain the greatest possible completeness.

Many laboratories have already earned our warmest thanks by sending us summaries of the contents of their publications.

We should be glad to see our endeavours aided by other laboratories and societies in the same manner, and to be placed in a position to be able to give information about all works of investigation in existence and all experiences obtained in the domain of the testing of materials.

*) If the publication be in French, German, or English, the title is given in the language in question in spaced type.

Liste des journaux indexés.
Liste der behandelten Zeitschriften.
Titles of the Journals indexed.

American Journal of Science.
American Machinist.
American Society Testing Materials, Proceedings.
Annales des Ponts et Chaussées.
Architect's and Builder's Magazine.
Ass. itat. per gli studi sui mat. d. costr.
Atti della Reale Academia dei Lincei.

Baumaterialienkunde.
Beton und Eisen.
Brass World.
British Fire Prevention Committee, Red Books.
Bull de la Société d'Encouragement pour l'Ind. Nat.
Bull. de l'Industrie Minérale.
Bull. du Laboratoire d'Essai du Conservatoire des Arts et Mét.
Bull. American Society Mining Engineers.
Bull. Engng. Experiment Station University of Illinois.
Bureau of Chemistry U. S. Dep. Agriculture, Bulletins, Circulars.
Bureau of Standards U. S. Dep. Comm. and Lab., Bull.

Calif. Journal of Techn.
Cement.
Cement Age.
Clay Record.
Concrete and Constructional Engeneering.

Den tekniske Forenings Tidskrift.
De Ingenieur, Gravenhage.
Deutsche Bauzeitung.
Dingler's Polytechnisches Journal.

Echo de l'Industrie.
Electrical Review, London.
Electrical Review, New York.
Electrical World.
Electrician.
Electrochemical and Met. Industry.
Engineer, Chicago.
Engineer, London.
Engineering.
Engineering and Mining Journal.
Engineering Contracting.
Engineering News.
Engineering Review, London.
Engineering Record.
Engineering Times.
Epitési Ipar, Budapest.

Fer et Acier.
Forest Service, U. S. Dep. Agric. Bulletins, Circulars.
Foundry.

Génie civil.
Gießerei-Zeitung.

Harvard Engng. Journal.

Ingeniören.
Ing. ferroviaria.
Iron Age.
Iron and Coal Trades Review.
Ironmonger.
Iron Trade Review.

Journal of the Frankline Institute.
Journal of the Inst. of Civil Engineers.
Journal of the R. Inst. of British Architects.
Journal of the Iron and Steel Institute.
Journal Soc. Chem. Ind.
Journal of the Worcester Polyt. Inst.
Journal of the U. S. Artillery.

La Locomotion Automobile.

Machinery.
Mechanical Engineer.
Mechanical World.
Mém. de la Société des Ingénieurs civils.
Mining Reporter.
Mines and Minerals.
Mitt. der k. k. forstlichen Versuchsanstalt Mariabrunn.
Mitt. des k. k. techn. Gewerbemuseums, Wien.
Mitt. des kgl. Materialprüfungsamts Groß-Lichterfelde.
Monitore Tecnico.
Municipal Engineering.

Oesterr. Wochenschrift für den öffentl. Baudienst.
Oesterr. Zeitschrift für Berg- und Hüttenwesen.
Oesterr. Zeitschrift für Optik und Mech.
Oesterr. Vierteljahrschr. für Forstwesen.
Office Public Roads U. S. Dep. Agric., Bulletins.

Practical Engineer.
Proc. Am. Institute Electr. Engineers.
Proc. Am. Soc. Civil Engineers.
Proc. Am. Soc. Mech. Engineers.
Proc. Inst. Civil Engineers.
Proc. Inst. Electr. Engineers.
Proc. Inst. Mec. Engineers.
Proc. Physical Society.

Railway Age.
Railroad Gazette.
Report of the Tests made at Watertown Arsenal, Mass.
Réunion des membres franç. et belges de l'Association Int. Ess. Mat., Procès verbaux.
Revue de l'Electricité.
Revue Electrochim. et Electromet.
Revue gén. des chemins de fer.
Revue gén. des Sciences.
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Revue de Mécanique.
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Revue Minéralogique.

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Sitzungsberichte d. kais. Akademie der Wissenschaften, Wien.
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U. S. Geological Survey, Dep. of Interior.

Zeitschrift der Dampfkessel-Untersuchungs- und Versicherungs-Gesellschaft, Wien.
Zeitschrift des österr. Ingenieur- u. Architekten-Vereines.
Zeitschrift des Vereines Deutscher Ingenieure.
Zeitschrift für anorganische Chemie.
Zentralblatt für Bauverwaltung.
Zeitschrift für Dampfkessel- und Maschinenbetr.

I.

Conditions de réception et méthodes d'essai normales *).
Einheitliche Lieferungsbedingnisse und Prüfungsverfahren*).
Standard Specifications and methods of testing*).

Méthodes d'essai des métaux et des alliages, des agglomérants hydrauliques, du bois, des tuyaux en terre cuite, en grès et en ciment, recommandées par le IVième Congrès de ***l'Association Internationale pour l'Essai des Matériaux*** *à Bruxelles 3—6 sept. 1906. — Paris, H. Dunod & E. Pinat. 1907.*

Verfahren zur Prüfung von Metallen und Legierungen, von hydraulischen Bindemitteln, von Holz, von Ton-, Steinzeug- und Zementrohren. Empfohlen von dem in Brüssel vom 3. bis 6. September 1906 abgehaltenen IV. Kongresse des ***Internationalen Verbandes für die Materialprüfung der Technik.*** *Leipzig und Wien, Franz Deuticke. 1907.*

Methods of testing metals and alloys, hydraulic cements and woods, clay, stoneware and cement pipes. Recommended by the IVth Congress of the ***International Association for Testing Materials,*** *held a Brussels, Sept. 3—6, 1906. London: E. & F. N. Spon, Ltd., New-York: Spon & Chamberlein.*

American Society for Testing Materials.

Univ. of Pennsylvania, Philadephia, Pa.

Standard Specifications.

Einheitliche Lieferungsbedingungen. — Conditions de réception normales.

1. Stand. Spec. for Structural Steel for Bridges, 1905. — Einh. Lfgsb. für Stahlmaterial für Brücken. — Cond. de réc. norm. pour l'acier de construction pour ponts.
2. Stand. Spec. for Structural Steel for Ships, 1901. — Einh. Lfgsb. für Stahlmaterial für Schiffe. — Cond. de réc. norm. pour l'acier pour constructions navales.

*) Dans cette catégorie les publications parues avant Septembre 1906 ont été indiquées.

*) Hier wurden auch Veröffentlichungen berücksichtigt, die vor September 1906 erschienen sind.

*) Publications belonging to the time previous to September 1906 would be dealt with here.

3. Stand. Spec. for Structural Steel for Buildings, 1901. — Einh. Lfgsb. für Stahlmaterial im Hochbau. — Cond. de réc. norm. pour l'acier de construction pour bâtiments.
4. Stand. Spec. for Open-Hearth Boiler Plate and Rivet Steel, 1901. — Einh. Lfgsb. für Martinstahl-Kesselblech und Nietstahl. — Cond. de réc. norm. pour les tôles de chaudière en acier Martin.
5. Stand. Spec. for Steel Rails, 1907. — Einh. Lfgsb. für Stahlschienen. — Cond. de réc. norm. pour les rails en acier.
6. Stand. Spec. for Steel Splice Bars, 1901. — Einh. Lfgsb. für Stoßverbindungslaschen. — Cond. de réc. norm. pour les éclisses en acier.
7. Stand. Spec. for Steel Axles, 1905. — Einh. Lfgsb. für Stahlachsen. — Cond. de réc. norm. pour les essieux en acier.
8. Stand. Spec. for Steel Tires, 1901. — Einh. Lfgsb. für Radreifen aus Stahl. — Cond. de réc. norm. pour les bandages en acier.
9. Stand. Spec. for Steel Forgings, 1905. — Einh. Lfgsb. für Schmiedestücke aus Stahl. — Cond. de réc. norm. pour pièces forgées.
10. Stand. Spec. for Steel Castings, 1905 — Einh. Lfgsb. für Stahlguß. — Cond. de réc. norm. pour des moulages d'acier.
11. Stand. Spec. for Wrought Iron, 1901. — Einh. Lfgsb. für Schmiedeeisen. — Cond. de réc. norm. pour le fer soudé.
12. Stand. Spec. for Foundry Pig Iron, 1904. — Einh. Lfgsb. für graues Roheisen. — Cond. de réc. norm. pour la fonte grise de moulage.
13. Stand. Spec. for Cast Iron Pipe and Special Castings, 1904. — Einh. Lfgsb. für Gußeisenrohre und Spezialguß. — Cond. de réc. norm. pour les tuyaux en fonte et l'acier spécial.
14. Stand. Spec. for Locomotive Cylinders, 1904. — Einh. Lfgsb. für Lokomotiv-Cylinder. — Cond. de réc. norm. pour les cylindres de locomotives.
15. Stand. Spec. for Cast Iron Car Wheels, 1905. — Einh. Lfgsb. für Gußeisen-Räder. — Cond. de réc. norm. pour les roues de voiture en fonte.
16. Stand. Spec. for Malleable Castings, 1904. — Einh. Lfgsb. für schmiedbaren Guß. — Cond. de réc. norm. pour la fonte malléable.
17. Stand. Spec. for Gray Iron Castings, 1905. — Einh. Lfgsb. für Grauguß. — Cond. de réc. norm. pour les moulages de fonte grise.
18. Stand. Spec. for Cement, 1904. — Einh. Lfgsb. für Zement. — Cond. de réc. norm. pour le ciment.
19. Stand. Test for Fireproof Floor Construction, 1907. — Einh. Lfgsb. für feuerfeste Deckenkonstruktionen. — Essais normaux des planchers réfractaires.
20. Stand. Spec. for Structural Timber, 1907. — Einh. Lfgsb. für Bauholz. — Cond. de réc. norm. pour les bois de construction.

Vorlagen des „Deutschen Verbandes für Materialprüfungen der Technik".

Prescriptions de l'Ass. allemande pour l'essai des matériaux.

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Groß-Lichterfelde W. 3.

Nr. 1. Grundsätze für einheitliche Materialprüfungen. 1900. — Principes pour l'unification des méthodes d'essai. — Principles for standardizing the methods of testing.

Nr. 2. Einheitliche Verfahren, um die Puzzolane auf ihren mörteltechnischen Wert zu prüfen. 1900. — Méthode normale pour l'essai

des puzzolanes au point de vue de leur valeur pour la fabrication des mortiers. — Standard methods for testing puzzolanas with the object of determining their value for mortar.

Nr. 23.*) Einheitliche Vorschriften für Oberbaueisen. 1904. — Prescriptions normales pour le matériel métallique de la voie. — Standard specifications for the permanent way iron material.

Nr. 24.*) Einheitliche Vorschriften für Bauwerkeisen (Eisenkonstruktionen für Brücken- und Hochbau). 1904. — Prescr. norm. pour le fer des charpentes métalliques. — Stand. spec. for bridge and building-construction iron.

Nr. 25.*) Einheitliche Vorschriften für Schiffbaueisen. 1904. — Prescr. norm. pour le fer des constructions navales. — Stand. spec. for iron for shipbuilding.

Nr. 26.*) Einheitliche Vorschriften für Walzrohre. 1904. — Prescr. norm. pour les tuyaux laminés. — Stand. spec. for rolled steel pipes.

Nr. 27.*) Einheitliche Vorschriften für Draht. 1904. — Presc. norm. pour le fil d'acier. — Stand. spec. for steel wire.

Nr. 32. Grundsätze für die Prüfung von Mineralschmierölen, von Leuchtöl (Mineralöl), Gasöl, Putzöl, Benzin und Paraffin. 1907. Principes pour l'essai des lubrifiants minéraux, pétrole lampant, gazoline, huiles lourdes, benzine et paraffine. — Principles for the testing of mineral lubricating oils, lighting oil (mineral oil), gas-oil, polishing oil, benzine, and paraffine, 1907.

Nr. 35. Die Kerbschlagprobe. 1907. — L'essai au choc sur barreaux entaillés. — Impact tests on notched bars.

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*) Als Vorarbeiten für die „Einheitlichen Vorschriften“ sind folgende **Ergebnisse von Sammelarbeiten** erschienen, in welchen die wichtigsten Vorschriften aller großen Staaten für die Qualität, Prüfung und Abnahme von Eisen- und Stahlmaterial aller Art zusammengefaßt sind:

*) Comme préparation aux „Prescriptions normales“, on a publié les **Résultats des travaux de documentation** ci-après, dans lesquels sont rassemblées les Prescriptions les plus importantes de tous les grands Etats relativement à la qualité, à l'essai et à la réception des matériaux de tout genre en fer et en acier:

*) As preliminary studies to the Standard specifications the following **"Results of Collecting Work"** have heen published, in which the most important prescriptions of all great states for the quality, testing and inspecting of all kind of iron and steel are condensed:

Ergebnisse der Sammelarbeiten.

Résultats des travaux de documentation. — Results of Collecting Work.

Heft I—VIII.

Vorlage Nr. 5. — Heft I. Zur Einführung. — Introduction. — Introduction.

Vorlage Nr. 6. — Heft II. Rollendes Material. — Matériel roulant. — Rolling stock.

Vorlage Nr. 7. — Heft III. Schiffbaueisen. — Fer pour constructions navales. — Iron for shipbuilding.

Vorlage Nr. 8. — Heft IV. Kesselbleche. — Tôles à chaudière. — Boiler plates.

Vorlage Nr. 9. — Heft V. Walz- und Gußrohre. — Tuyaux en fer laminé et en fonte. — Rolled and cast pipes

Vorlage Nr. 10. — Heft VI. Telegraphen- und Telephondrähte. — Fils télégraphiques et téléphoniques. — Telegraph and telephone wires.

Vorlage Nr. 11. — Heft VII. Oberbaueisen. — Matériel métallique de la voie. Permanent-way iron-material

Vorlage Nr. 12. — Heft VIII. Bauwerkeisen. — Fer pour charpentes métalliques. — Structural iron for bridges and buildings.

Publications of the Engineering Standards Committee.

28, Victoria Street, Westminster, London, S. W.

British Standard Specifications.

Einheitliche britische Lieferungsbedingnisse. — Conditions de réception normales pour la Grande-Bretagne.

Nr. 2. Spec. and Sections of British Standard Tramway Rails and Fishplates. 1903. — Bedingnisse und Querschnitte der einheitlichen Britischen Tramway-Schiene und -Lasche. — Cond. de réc. et section des rails et des éclisses norm. des tramvays.

Nr. 9. Brit. Stand. Spec. and Sections of Bull-headed Railway Rails. 1904. — Einh. brit. Lfgsb. und Querschnitte der Doppelkopf-Schiene. — Cond. de réc. norm. et section des rails à double champignons.

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Nr. 12. Brit. Stand. Spec. for Portland Cement, 1907. — Einh. brit. Lfgsb. für Portlandzement. — Cond. de réc. norm. pour le Ciment Portland.

Nr. 13. Brit. Stand. Spec. for Structural Steel for Shipbuilding, 1906. — Einh. brit. Lfgsb. für Stahlmaterial für den Schiffsbau. — Cond. de réc. norm. pour l'acier des constructions navales.

Nr. 14. Brit. Stand. Spec. for Structural Steel for Marine Boilers, 1907. — Einh. brit. Lfgsb. für Stahlmaterial der Schiffskessel. — Cond. de réc. norm. pour l'acier des chaudières marines.

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Nr. 16. Brit. Stand. Spec. and Tables for Telegraph Material, 1905. — Einh. brit. Lfgsb. und Tabellen für Telegraphenmaterial. — Cond. de réc. norm. et tables pour le matériel télégraphique.

Nr. 18. Forms of Standard Tensile Test Pieces, 1907. — Einheitliche Form des Zerreißprobestabs. — Dimensions des éprouvettes normales pour les essais de traction.

Nr. 24. Brit. Stand. Spec. for Material used in the Construction of Railway Rolling Stock, 1907. — Einh. brit. Lfgsb. für das Konstruktionsmaterial der Eisenbahn-Fahrbetriebsmittel. — Cond. de réc. norm. pour les matériaux de construction du matériel roulant des chemins de fer.

Nr. 29. Brit. Stand. Spec. for Ingot Steel Forgings for Marine Purposes, 1907. — Einh brit. Lfgsb. für Schmiedestücke aus Tiegelstahl für Schiffsbauzwecke. — Cond. de réc. norm. pour les pièces de forge en acier pour la construction navale.

Nr. 30. Brit. Stand. Spec. for Steel Castings for Marine Purposes, 1907. — Einh. brit. Lfgsb. für Stahlguß für Schiffsbauzwecke. — Cond. de réc. norm. pour les moulages d'acier pour la construction navale.

Nr. 31. Brit. Stand. Spec. for Steel. Conducts for Electric Wiring, 1906. — Einh. brit. Lfgsb. für elektrische Leitungen aus Stahl. — Cond. de réc. norm. pour les câbles conducteurs électriques en acier.

Nr. 32. Brit. Stand. Spec. for Steel Bars for use in Automatic Machines, 1907. — Einh. brit. Lfgsb. für Stahl zum Bau von automatischen Drehmaschinen. — Cond. de réc. norm. des barres d'acier pour machines automatiques à décolleter.

Nr. 33. Brit. Stand. Spec. for Carbon Filament Glow Lamps, 1906. — Einh. brit. Lfgsb. für den Kohlenfaden der Glühlampen. — Cond. de réc. norm. des filaments de charbon pour lampes à incandescence.

Nr. 35. Brit Stand. Spec. for Copper Alloy Bars for use in Automatic Machines, 1907. — Einh. brit. Lfgsb. für Stangenkupfer zum Bau von automatischen Drehmaschinen. — Cond. de réc. norm. des barres en laiton ou bronze pour machines automatiques à décolleter.

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3. Cond. de réc. norm. pour les tuyaux en fonte et en fer forgé. — Einh. Lfgsb. für guß- und schmiedeeiserne Röhren. — Stand. Spec. for cast and wrought iron pipes, 1904.
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Österreichischer Ingenieur- und Architekten-Verein
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II.

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INTERNATIONAL ASSOCIATION □ FOR TESTING MATERIALS □

General Secretary's Office: Vienna, Austria, II/2, Nordbahnstraße 50.

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Those wishing to join the International Association should apply:

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„ AUSTRALIA, to Prof. W. H. Warren, University of Sydney.

Papers of the IV^th^ Congress, held at Brussels 1906.

These can be obtained from the General Secretary at the rate of 0.25—1 K each. The Minutes of the Congress Proceedings 2 K a copy. (1 K = 10 d = 20 cents.)

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"Methods of Testing metals and alloys; hydraulic cements and woods; clay, stoneware; and cement pipes", recommended by the IVth Congress. E. & F. N. Spon Ltd., London. Spon & Chamberlain, New York. (Price 1 s.)

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Contents:

The invitation of the Organisation Committee is inclosed with this number.

The Vth International Congress for Testing Materials.

The Vth Congress of the International Association for Testing Materials will be held under the Patronage of His Majesty King Frederick VIIIth of Denmark, September 7–11th 1909 in Copenhagen.

With the exception of delegates from public bodies, only members of the Association will take part in the Congress*).

The programme has been drawn up as follows:

Tuesday, September 7th: General Meeting.

Ceremonial Opening of the Congress in the presence of His Majesty the King of Denmark.

Welcoming of the delegates and members.

Address by the Prime Minister.

Business Report of the President of the Association.

Paper read by Mr. *Poul Larsen* on the "Development of the Cement industry in Denmark".

Evening: Reception at Danish Institute of Engineers.

*) For membership see last page.

Wednesday, September 8th: Meetings of the Sections.
Evening: Reception of the Members of the Congress in the Town Hall by the heads of the Municipality, afterwards visit to the Tivoli.

Thursday, September 9th: Meetings of the Sections.
Evening: Free.

Friday, September 10th: Meetings of the Sections.
Later, inspection of the harbour of Copenhagen by steamer; dinner in the watering-place of Skodsborg.

Saturday, September 11th: Final General Meeting. Reports of the Sections, and drawing up of Resolutions. Paper read by Mr. *J. E. Stead* of Middlesborough "On the practical Use of the Microscope in Testing Metals and Alloys". Close of the Congress. Afterwards excursion to Helsingör. Visit to the Castle of Kronberg, and farewell festival at Marienlyst.

The inspection of various sights of technical interest in Copenhagen will take place in the course of the Congress days.

The Member's subscription has been fixed at 20 Danish Crowns (26·70 Frcs.) for gentlemen, and at 12 Danish Crowns (16 Frcs.) for ladies.

Names must be sent in, accompanied by the above amount, at latest by June 1st to the Council Delegates or Mandatories for the respective countries, and these gentlemen will forward the names to the Organisation Committee in Copenhagen (address: Dansk Ingenierforening, Amaliegade 38, Copenhagen), and a copy to the Office of the General Secretary, Wien II., Nordbahnstraße 50.

Great 5 days excursion to Jutland from Sunday 12th to Friday 17th.

After the close of the Congress.

Sunday, September 12th: Evening: Departure by steamer to Aalborg to visit the Cement Works there. From there, either by rail to Skagen or to the North Sea coast to inspect the great coast-preservation constructions. The members of both parties will meet at Aarhus to visit the National Exhibition. The expenses of this excursion are not included in the member's subscription.

Congress papers.

The following list of papers will be issued to be discussed at the Congress. All these papers will be published in the "Proceedings" and distributed in a trilingual edition gratis to all members of the International Association.

The Congress members will receive further a supplement containing expanded reports of some of the papers, each in its original language. These supplements as well as the "Proceedings" will be obtainable at all booksellers.

A. Metals.

a) **Metallography.** Official Report by Prof. *E. Heyn*, Gr.-Lichterfelde.
Special Steels by Prof. *L. Guillet*, Paris.
The Heat Treatment of Spring Steel by *Lawford H. Fry*, Paris.
On a Metallographical subject: by *W. Rosenhain*, Teddington.

b) **Hardness Testing.** Official Report by Dr. *F. Ludwik*, Vienna.
Simplified Apparatus for Ball Pressure Tests by Prof. *E. Heyn* and *A. Martens*, Gr.-Lichterfelde.
The Cone Pressure Test used for the Determination of the Hardness of Iron Superstructure Material by Dr. *A. Gessner*, Vienna.
On the Brinell Method of Hardness Determination by *H. Moore*, London.

c) **Impact Tests.** Official Report by *G. Charpy*, Paris.
The Definition of Resilience in Connection with Impact Tests by *L. Revillon*, Paris.
Impact Tests on Notched Bars at Different Temperatures by Prof. *L. Guillet* and *L. Revillon*, Paris.
On Impact Tensile Tests by *P. Breuil*, Paris.
On Impact Bending Tests on Notched Bars by Prof. *F. Schüle* and *E. Brunner*, Zurich.
Comparative Statical and Dynamical Notched-Bar-Tests by Dr. *A. Leon* and Dr. *P. Ludwik*, Vienna.
Application of Modern Testing Methods to Alloys of Copper by *L. Guillet* and *L. Revillon*, Paris.
The Dynamic Load and Impact Tests by *Welikhoff*, Moscow.
On Piece Tests of Important Structural Parts by *O. Hönigsberg*, Vienna.

d) **Testing Metals by Alternating Stresses.** Official Report by *J. E. Howard*, Watertown.

Quality and Time Tests of Copper wire by Prof. *F. Schüle* and *E. Brunner*, Zurich.

e) **Testing of Cast Iron.** Official Report by Dr. *R. Moldenke*, New York.

On the Testing of Cast Iron by the *Brothers Sulzer*, Winterthur.

f) **Influence of Increased Temperature on the Mechanical Qualities of Metals.** Official Report by Prof. *M. Rudeloff*, Gr.-Lichterfelde W.

Not belonging to any Principal Question.

On a new Mirror-Apparatus for the Measurement of Elasticity by Prof. *B. Kirsch*, Vienna.

Reports on Problem 28: "Magnetic and Electric Properties of Materials in Connection with their Mechanical Testing".

Report by *A. Grünhut* and Dr. *Wahn*, Vienna.

Ferro-Magnetism by Prof. *P. Weiss*, Zurich.

Method for determining elastic strength limit by means of thermo-electric measurements by *Ew. Rasch*, Gr.-Lichterfelde.

Report by Prof. *J. W. Esterline*, Lafayette.

Report on Problem 24: "Nomenclature of Iron and Steel with a Definition of their Microscopic Constituents" by Prof. *M. H. M. Howe*, New York and Prof. *A. Sauveur*, Boston.

Report on Problem 1: "International specifications for Testing and Inspecting Iron and Steel" by Dr. *A. Rieppel*, Nuremberg.

Report on Problem 38: "Principles for Specifications of Copper" by Prof. *L. Guillet*, Paris.

Conclusions drawn from Studies on the Qualities of Rails, as Basis for Conditions of Tender for Rails by Prof. Dr. *N. Belelubsky*, St. Petersburg.

Unification of Methods for Testing Steam, Gas and Water Pipes by A. C. Karsten or Prof. *H. I. Hannover*, Copenhagen.

The Spark Method for Grading Steels by *M. Bermann*, Budapest.

On Internal Friction in Loaded Materials by Prof. *G. H. Gulliver*, Edinburgh.

Relating to the Principles of Technological Mechanics by Dr. *P. Ludwik*, Vienna.

Tenacity and Ductility by Dr. *Misangyi*, Budapest.

The Connection between the Permanent Sets produced by Tensile and Compressive Strains respectively, by Dr. *Misangyi*, Budapest.

General Korobkoff's definition of the tenacity by Prof. *N. Belelubsky*, St. Petersbourgh.

B. Cement, Stones, Concrete.

g) **Reinforced Concrete.** Official Report by Prof. *F. Schüle*, Zurich.

Experimental Researches on the Subject of Building Constructions by *Ch. Rabut*, Versailles.

On accidents in connection with Reinforced Concrete Structures by Dr. *F. v. Emperger*, Vienna.

On Disturbances in the Bond between Different Materials by Dr. *A. Leon*, Vienna.

Contribution to Methods of Investigation into the Elastic Longitudinal Deformation of Concrete by Dr. *B. v. Bresztowsky*, Budapest.

Influence of Repeated Strains on the Bond between Concrete and Iron with Clean and with Corroded Surface by Prof. *B. Kirsch*, Vienna.

The influence of Thin Transverse Connections on the Strength of Concrete by *W. Nekrassow*, St. Petersburg.

h) **Progress in the Methods of Testing**, Official Report by *R. Feret*, Boulogne-sur-mer.

Report on Problem 9: "Rapid Tests for Determining the Strength of Hydraulic Cements" by Dr. *F. Berger*, Vienna.

Report on the same Problem by *E. Deval*, Paris.

Report on the same Problem by *A. Greil*, Vienna.

Report on Problem 30: "Simplest Method for the Separation of the Finest Particles in Portland Cement by Liquid and Air Process" by Prof. *M. Gary*, Gr.-Lichterfelde.

Report on the Work done by the Commission 11: "Testing Puzzolanas with the Object of Determining their Value for Mortars" by *G. Herfeldt*, Andernach.

Report on Problem 40: "Unification of Specifications for Gypsum" by Prof. *M. Gary*, Gr.-Lichterfelde, and *R. Feret*, Boulogne-sur-mer.

i) **Tests by means of Prisms and Standard Sand.** Official Report by Prof. *F. Schüle*, Zurich.

j) **Constancy of Volume.** Official Report by *B. Blount*, London.

k) **Cement in Sea Water.** Official Report by Prof. *W. Czarnomsky* and *A. Baykoff*, St. Petersburg.

Experiments on the decomposition of mortars in sulphurated water by *J. Bied,* du Teil.

Experiments with Reinforced Concrete in Sea Water by Prof. *M. Möller*, Braunschweig.

Cement in Sea Water by *A. Poulsen*, Copenhagen.

l) **Weathering Resistance of Building Stones.** Official Report by Prof. *A. Hanisch*, Vienna.

Relating to the theory of the influence of frost on natural stones by Prof. Dr. *H. Seipp*.

Model for testing stones by Prof. Dr. *J. Hirschwald*, Charlottenburg.

On the resistance to frost by *E. Leduc*, Paris.

Not belonging to any Principal Question.

On the Binding of Mortar after several Interruptions in the Work by Prof. *B. Kirsch*, Vienna.

On the Strength, Elasticity-, Water-Permeability and Setting Qualities of Trass, Trass Cement and Cement Lime Mortars by Dr. *H. Renezeder*, Vienna.

On the Specific Heat of Refractory Materials at High Temperatures by Dr. *J. W. Mellor*, Stoke-on-Trent.

C. Sundries.

m) **Oils.** Official Report by Dr. *M. Albrecht*, Hamburg.

n) **Caoutchouc.** Official Report by *E. Camerman*, Brussels.

Mechanical Testing of Caoutchouc by *P. Breuil*, Paris.

o) **Wood.** Official Report by Prof. *W. K. Hatt,* Lafayette.

p) **Paints on Metallic Structures.**

Official Report by *S. S. Vorhees*, Washington.

Attacks on Iron by Water and Aqueous Solutions. Official Report by Prof. *E. Heyn*, Gr.-Lichterfelde.

On Paints on Metallic Structures by *E. Camerman*, Brussels.

A Plea for International Investigation concerning Protective Coatings for Iron and Steel by *J. Cruickshank Smith*, London.

Not belonging to any Principal Question.

On the International Technical Regulation of Testing by Dr. *W. Exner*, Vienna.

Testing in the Domain of Automobile Work by Dr. *W. Exner*, Vienna.

Personal Matters.

† **Prof. Dr. J. Thomsen.** The Organisation Committee have experienced a severe loss in the death of the renowned Danish savant, His Excellency Prof. Dr. Julius Thomsen in Copenhagen, who was to have take part in the Congress as Honorary Member. The world of science laments with them the loss of the author of the celebrated work on thermo-electrical investigations.

Mr. G. C. Lloyd, the recently nominated Secretary of the Iron and Steel Institute, has been elected Council's Delegate for Great Britain in place of the late Mr. B. H. Brough.

Mr. E. Bian, Director of Forges d'Eich in Dommeldange has undertaken the office of Mandatory for Luxemburg.

Mr. J. O. Roos af Hjelmsäter, Manager of the Institute for Testing Materials in Stockholm, has kindly consented to act for the Swedish Delegate Mr. G. Dillner in the business of the Association untill the fresh election.

Changes in the Committees.

Committee 1. (International Specifications for Iron and Steel). Director *G. Vehling* of Rothe Erde (Aix la Chapelle) and Prof. *R. Stribeck* for Krupp's (Essen) have joined subcommittee 1.

Committee 7 (Weathering of Stones.) Prof. *M. Gary* (Groß-Lichterfelde) Prof. Dr. *J. Hirschwald* (Charlottenburg) and Mr. *E. Leduc* (Paris) have joined the committee,

Committee 24. (Uniform Nomenclature of Iron and Steel.) Mr. *J. E. Stead* F. R. S. (Middlesborough) and Mr. *F. W. Harbord* (London) have joined the committee.

Committee 30. (Finest Particles in Portland Cement.) Owing to the decease of Mr. *Lejeune*, Mr. *R. Feret* (Boulogne-sur-mer) has entered the committee.

Committee 38. (Specification for Copper.) Prof. *L. R. v. Stockert* (Vienna), on whose proposal this committee has been instituted, resigned his functions owing to his state of health.

Committee 41. (Reinforced Concrete.) Mr. *W. Dunn* F.R.I.,B.A. (London) has entered the committee as representative of the Concrete Institute, Prof. *W. C. Unwin* F. R. S. (London) as representative of the Institution of Civil Engineers.

Minutes

of Proceedings of the XVIIIth Council's Meeting held at Frankfort-on-Main in the Hôtel Continental, February 6th 1909.

Meeting opened 10. a. m.

Chairman:

Mr. *Alexander Foss* from Copenhagen.

The following were also present:

The Vice-chairman:

Professor Dr. *A. Martens* from Gross-Lichterfelde.
Professor Dr. *N. Belelubski* from St. Petersburg.

Council's Delegates and Mandatories:

Mr. *L. Bienfait* from Amsterdam.
Mr. *A. Greiner* from Seraing.
Mr. *A. Granfelt* from Helsingfors.
Professor *H. I. Hannover* from Copenhagen.
Professor *B. Kirsch* from Vienna.
Mr. *G. C. Lloyd* from London.
Professor *A. Mesnager* from Paris.
Mr. *J. O. Roos af Hjelmsäter* from Stockholm acting for Mr. *G. Dillner.*
Professor *F. Schüle* from Zurich.

Further the following gentlemen:

Mr. *H. de Gorski* accompanying Mr. *A. Greiner.*
Captain *A. G. V. Petersen* accompanying Mr. *Foss.*

Secretary:

Mr. *E. Reitler* General Secretary.

The *Chairman* opened the meeting, and thanked the gentlemen present for their attendance in so large a number, more especially those, who, like the gentlemen from Helsingfors, St. Petersburg and Stockholm, had not been afraid of a long journey for the purpose; he further expressed his regret that he had been unable to attend the Council's Meeting at Munich in the previous year.

The following gentlemen sent excuses for non-appearance:

Dr. *F. Berger*, who having started on his journey to Frankfort had been forced to turn back through the railway communication being broken.

Further:

Mr. *E. Bian* from Dommeldingen.
Mr. *C. v. Banovits* from Budapest.
Professor *J. Benetti* from Bologna.
Mr. *J. da P. Castanheira das Neves* from Lisbon.
Mr. *Ch. Dudley* from Altoona, U. S. A.
Mr. *S. A. Lund* from Christiania.
General *J. Marva y Majer* from Madrid.
Mr. *M. Milasinovic* from Belgrade.

Point 1 of Business in hand.

Passing of Minutes of XVIIth Council's Meeting.

Minutes passed.

Point 2.

Changes in the Council.

The *President* spoke in words of the warmest appreciation of the deceased Mr. *Bennett H. Brough*, late council's Member for Great Britain, whose death had occurred since the last Meeting, particularly emphasising in his speech the gratitude and the obligations of the Association towards Mr. *Brough* for his active promotion of the objects and interests of the Association in Great Britain, where the Association's principles of unification

had met with much opposition. — He referred to the ready kindness of Mr. *L. P. Sidney* in acting as substitute, and offered a cordial welcome to Mr. *G. C. Lloyd*, the recently nominated Secretary of the Iron and Steel Institute, and newly elected Council's Delegate for Great Britain. In the course of his speech he laid particular stress on the importance of he English speaking nations joining in the work of the Association. Finally the expressed the thanks of the Meeting to the governing body of that Institute, who, by agreeing to the election of Mr. *Lloyd* as Council's Delegate, had given a fresh proof of their goodwill towards the Association.

The *President* announced that Mr. *E. Bian* Director of Forges d'Eich in Dommeldange had undertaken the office of Mandatory for Luxembourg, and thanked that gentlemen for the propaganda made by him for the Association.

Mr. *Roos af Hjelmsäter*, Manager of the Institute for Testing Materials in Stockholm, whom the president welcomed, had kindly consented to act for Mr. *G. Dillner* in the business of the Association, until the fresh election.

Point 3.

Changes in Number of Members.

The Number of Members at the end of 1908 is as follows:

Argentines	1	Japan	1
Australia	17	Luxembourg	9
Austria	193	Norway	40
Belgium	75	Portugal	14
Brasil	2	Roumania	19
Chili	2	Russia (Finland 29)	231
Denmark	79	Servia	3
France	163	Spain	27
Germany	370	Sweden	49
Great Britain	75	Switzerland	71
Holland	42	United States of North America	293
Hungary	69		
Italy	55		

Amount end of 1908: 1900.

Professor *Belelubsky* notified that the number of Russian member has for various reasons decreased in the last years, but he is sure that within the next months the original number will be made up again.

Prof. Dr. *Edgar Marburg* of Philadelphia had especially earned the gratitude of the Association through the exertions made by him to increase the number of members in America.

Point 4.

Work of the Central Office.

The *General Secretary* made the following communications:

Of the "Proceedings", Numbers 1—3 had already appeared. The review, begun in No 3, had given as comprehensive a survey as possible of the publications under every head in the domain of Testing Materials for the period from the IVth Congress down to the end of 1907 — besides the publications of the National Associations and the laboratories.

It had thus gone beyond the "Hints as to specially important Articles from various periodicals in all Countries, pointed out by Council members" — proposed in the XVIIth Council's Meeting because such a selection had proved not to be feasible. The cost of printing such a review would therefore come in round numbers to 1000 francs a year. The "Proceedings" are published on commission by E. & F. N. Spon L^{td}, London, Julius Springer, Berlin, Dunod and Pinat, Paris. It is intended to put the whole volumes 1906—1909 of all the "Proceedings" upon the market, or simply the Congress Reports and Minutes alone in one volume, a form of publication promising — in America particularly — more success than the issue of single numbers. The attempt to make the "Proceedings" into a source of profit by the insertion of advertisements has already been started.

The Council took note of these communications, and recommended the pursuing of the course thus entered upon. The wish was expressed that the review might be extended to other languages such as Russian, Japanese etc. The *General Secretary* begged the Council Delegates and the Mandatories to assist him by sending in hints as to laboratory work in their own countries, in order to make the review as comprehensive as possible.

Point 5.

Changes in the Committees.

The correspondence was read as to the changes in the committees published in No. 3 of the "Proceedings".

Dr. *Rieppel*, Chairman of the Committee for International Specification for Iron and Steel, communicates that Director *G. Vehling* of the Work Rothe Erde (Aachen) and Prof. *R. Stribeck* from Krupp's (Essen) have joined Sub-committee I, in which Germany, Great Britain and U. S. A. were now represented. Professor *M. Gary* (Gross-Lichterfelde), Professor *J. Hirschwald* (Charlottenburg), and Professor *E. Leduc* (Paris), have joined Commission 7 (Weathering of Stones).

Professor *L. R. von Stockert*, on whose proposal the Copper Committee has been instituted, has written, that, owing to his state of health, he has been forced to lay down his offices.

On the motion of Mr. *G. C. Lloyd* it was decided to invite the Institution of Civil Engineers to send a representative to the Reinforced-Concrete-Committee. Mr. *William Dunn* F. R. I. B. A. was also begged to join the Committee as the representative of the Concrete Institute.

The further motion of Mr. *Lloyd*, that Messrs *J. E. Stead* and *F. W. Harbord* should be appointed to Committee 24 (Nomenclature of Iron and Steel), was agreed to, on the supposition that the work of the Committee has not yet been definitely completed.

On the motion of Professor *Mesnager*, Mr. *R. Feret* of Boulogne-sur-mer was elected to Committee 30 (Finest Particles) in place of Mr, *Lejeune* deceased.

Point 6.

Financial Report.

The *President* brought forward the financial report given below. Several countries not having yet paid the amounts owing for 1908, the receipts are about 1000 francs in arrear of the budget. Among the expenses appears the increased amount for printing in the general administration, the reason for which has already been assigned as a consequence of the publication of the

Review in the "Proceedings". The year is closed with a balance of 2259·80 francs. Messrs *A. Granfeld* and *L. Bienfait* were requested to undertake the auditing of the books by the afternoon.

Funds of the Association end 1908.

Balance in hand of the Delegates and Mandatories see A	Frcs.	1581·41
Balance of the Head cash see B	„	2259·80
Total . .	Frcs.	3841·21

A.

Receipts and Expenditure of the Members of Council and Mandatories for the year 1908.

Country	Balance on 1907	Subscriptions and Subventions received	Total	Paid into Head cash office	Expenditure	Cash in hand on 31s December 1908
	Frcs.	Frcs.	Frcs.	Frcs.	Frcs.	Frcs.
Australia	—·—	157·50	157·50	157·50	—·—	—·—
Austria	264·41	2.505·71	2.770·12	1.890·—	605·23	274·89
Belgium	—·—	562·50	562·50	553·—	9·50	—·—
Denmark	43·43	653·19	696·62	574·56	44·59	77·47
Finland	—13·70	218·50	203·80	213·10	4·40	—13·70
France	—·—	1 260·—	1.260·—	1.157·55	102·45	—·—
Germany	507·62	4·315·81	4 823·43	3.375·—	571·85	876·58
Great Britain	—·—	712·50	712 50	660·—	52·50	—·—
Holland	71·82	317·52	389·34	262·50	39·75	87·09
Hungary	14·04	574·44	588·18	462·—	30·91	95·27
Italy †)	37·10	—·—	37·10	—·—	—·—	37·10
Luxemburg	—·—	45·—	45·—	45·—	—·—	—·—
Norway †)	85·78	—·—	85·78	—·—	—·—	85·78
Portugal	—·35	105·—	105·35	88·55	6·80	10·—
Roumania †)	*) —5·—	*) 162·50	*) 157·50	*) 110·—	*) 25·20	*) 22·30
Russia †)	—·—	525·—	525·—	525·—	—·—	—·—
Servia	—·—	22·50	22·50	22·50	1·25	—1·25
Spain	—·—	202·50	202·50	202·50	—·—	—·—
Sweden †)	—·—	—·—	—·—	—·—	—·—	—·—
Switzerland	37 43	662 50	699·93	576·65	93·40	29·88
United States of America	—·—	2.298 78	2.298·78	2.178·96	119 82	—·—
Total	1.043·28	15.300·15	16.343·43	13.054·37	1.707·65	1.581·41

†) No accounts sent in for 1908.

*) Refers to paymant delayed from 1907.

B. Receipts and Expenses of the Central Office for 1908.

Receipts	Amount Frcs.	Estimate Frcs.
Credit carried over from year 1907 . .	1.621·27	1.621·27
Members Subscriptions, and Subventions:		
a) From the Council's Delegates and Mandatories	13.054·37*	13.980·—
b) Received direct:		
from Great Britain .....Frcs. 7·50		
„ Greece .... „ 15·—		
„ Japan .... „ 15·—		
„ Luxembourg ..... „ 22·—		
„ Sweden .... „ 138·—	198·88	
Interest	75·40	
Profit from Sale of Congress-papers . .	68·33	
Total . . .	15.018·25	

Expenses	Amount Frcs.	Estimate Frcs.
Salaries and Office	7.560·—	7.560·—
Expenses Residue from Printing and postage expenses of IVth Congress Minutes	1.806·90	1.600·—
Members cards, Circulars etc.	369·39	2.100·—
Printing and postage expense of "Proceedings" Nos 1, 2 and 3	2.468·78	
Translations to complete "Technical Review"	101·85	
Preliminary expenses for Vth Congress	—	
Postage	199·35	400·—
Miscellaneous (Exchange Differences etc.)	252·18	200·—
Credit carried on*)	2.259·80	3.891·27
Total . . .	15.018.25	

*) The Members Subscriptions from Italy, Norway, Roumania and Sweden pro 1908 (about 1100 Frcs.) have not yet come in.

Point 7.

Preparations for the V[th] Congress.

Report on the Congress-Programme and on the Work of the Organisation Committee.

The *President* reported as follows:

His Majesty King Frederick VIII[th] has consented to be Patron, and will probably attend the opening meeting of the Congress. *His Royal Highness the Crown Prince Christian* has kindly agreed to be honorary president of the Congress. The *Prime Minister*, the *Minister for Foreign affairs,* the *Minister of the Interior and the Minister for Public Works,* as well as the *Presidents of the House of Peers and of the House of Commons*, the *Mayor* of Copenhagen, and Prof. *Jul. Thomsen* P. C.*) will officiate *Mayor* as honorary members of the Congress. It is to be hoped that foreign governments will be largely represented by delegates. These governments have been invited by the Foreign Office in Copenhagen through diplomatic channels; and direct invitations have further been despatched by the President to the various authorities and public bodies of these countries, the necessary information having been provided by Council's Members of the Association or obtained through the respective legations.

With the exception of delegates from public bodies, only members of the Association are to take part in the Congress.

A Council's Meeting has already been planned for September 5[th].

The following programme has been drawn up. (See page 1.)

The Member's subscription has been fixed at 20 Danish Crowns (26.70 Frcs.) for gentlemen, and at 12 Danish Crowns (16 Frcs.) for ladies.

Names must be sent in, accompanied by the above amount, at latest by June 1[th] to the Council Delegates on Mandatories for the respective countries, and these gentlemen will forward the names to the Organisation Committee in Copenhagen (address: Dansk Ingenierforening, Amaliegade 38, Copenhagen), and a copy to the Office of the General Secretary, Wien, II., Nordbahnstraße 50.

The Meeting took note of these communications with expressions of the warmest thanks to the President.

*) Prof. J. Thomsen has since died.

The *President* further announced that steps were being taken to arrange the election of Chairmen of Sections in good time, and to insure the co-operation of specialists as interpreters; and requested the support of the Council's Delegates in the matter. To make the transactions of the Congress as successful as possible, members will be begged to announce as early as possible their intention of taking part in any discussions; and in order to have the Minutes of the Congress as exact as possible, the speakers will be begged to give a short abstract of their speeches immediately after the sitting, for which purpose shorthand writers will be at their disposal. Care will be taken, by means of a judicious distribution of the sectional meetings, to meet the wish expressed that members might be enabled to attend important transactions of Sections *A* and *B*.

Resolutions passed on the papers presented..

Before reading the titles of the papers already sent in or announced, the President informed the Meeting that, at the suggestion of Messrs *Belelubsky* and *Schüle*, the Council's Members assembled at Basel on October 12th for the Meeting of the Concrete Iron Commission, viz: Messrs *Martens, Schüle, Kirsch, Belelubsky* and *Mesnager,* had made proposals for the nomination of Referees for Principal Questions a) to p). On receipt of the invitations sent out in the President's name, the gentlemen designated below as official referees had in the most obliging manner expressed their willingness to act.

(For list of papers see page 3—7.)

The Meeting was suspended at 1 p. m. Resumed at 3 p. m.

After a long consultation the following points were decided upon:

1. The accepting of Congress Papers to be regarded as closed with the foregoing list.

2. Reports already published, wholly or in part, in any journal or in any language whatever, can only be given as brief abstracts.

3. It is decided on principle that this time all reports, either in their full extent or as abstracts, shall be published in the "Proceedings" in three languages, and in this way come to the knowledge of all the members.

As to the amount to be printed, the following points were decided upon, in view of the limited means at the disposal of the Association.

a) All reports of official referees on Principal Questions, as well as of the Chairmen of Committees, and official referees on technical problems, to be published in full in three languages. With regard to Problem 28: "Magnetic and Electric Qualities", for which there are four referees, the wish was expressed, if possible, to limit the edition in three languages to half a printed sheet each.

b) With regard to all other reports, certain distinctions to be made:

1. Up to a maximum of 8 pages in length, they can likewise be published in full in three languages, if the principles determined on above do not demand any further modification.

2. If the reports exceed 8 pages, the authors are to be begged to reduce their reports to 8 pages, the reports then being treated as under head b 1. If this, however, is not feasible, the authors are to be begged to send in brief abstracts, of about 4 pages in length, which will be published in three languages in the "Proceedings"; while the actual report, likewise abridged as far as possible, will appear in the original language in the "Supplement to the Papers laid before Congress".

Thus, while all the members of the Association will be informed — either in extenso or by abstract — of the contents of every single report, in a trilingual edition in the "Proceedings", the Supplements will provide the members of the Congress gratis with single expanded reports in one language. The „Proceedings" as well as these Supplements will also be on sale at the booksellers.

The General Secretary is therefore commissioned, in accordance with these principles, to approach those gentlemen, whose reports require an abridgement, or also the addition of an abstract. The General Secretary will have at the same time to point out that the Council, in all their public notices, have repeatedly declared themselves only able to print reports to the extent of 8 pages.

In conclusion the Council decide to recommend on principle, for the future, that notification should be given clearly and distinctly that reports from officially nominated referees can only be accepted in the length of 8—16 pages, and all other reports only up to 8 pages.

On the basis of the decisions thus made, the General Secretary estimated the expenses of the trilingual edition of the reports, as well as the cost of the "Supplements to the Congress Papers"

at	Francs 25.800
the expense of printing congress papers at . .	„ 5.000
Total . .	Francs 30.800
According to estimate, the following funds are in hand:	Francs 5.800
There remains, therefore, for the covering of the expense of printing congress papers to the above extent, a deficit of:	Francs 25.000

The President, in the name of the Organising Committee of Copenhagen, declared his willingness to provide the amount.

The offer was accepted by the Meeting with the warmest expressions of gratitude, and the estimate therefore ratified and passed as follows.

Plan of Budget, Treasurer's Department for the year 1909.

Receipts	Frcs.	Expenses	Frcs.
Credit carried on 1908 .	2.259·80	Salaries and office expenses	7.560·—
Supplementary Members Subscriptions for 1908	1.100·—	Postage	400·—
Members' Subscriptions and Subventions for 1909	14.000·—	Miscellaneous (Exchange differences, charges etc.)	500·—
Interest	70·—	Members' tickets, circulars etc.	500·—
Profit from "Proceedings"	500·—	Publication of "Proceedings" Minutes of the XVIIIth Council's Meeting . . . . 500 Minutes of the XIXth Council's Meeting . . . . 200 List of Members . 1.000 Review Jan. 1th 1908 — Congress . . 1.200 Congress papers . 25.800 Congress Minutes . 5.000	33.700·—
Subvention of the Copenhagen Committee . . .	25.000·—	Unforeseen Congress expenses	269·80
Total . . .	42.929·80	Total . . .	42.929·80

At the request of the *President*, the two auditors, Messrs *Granfelt* and *Bienfait*, presented their report. They had found the books in order, and the outstanding balance shown of Frcs. 2259·80 correct. The further expenses and receipts from January 1th up to the present day show a budget of 2246.04 Frcs. which sum is deposited. according to receipt produced, in the "Allgemeinen Depositenbank" in Vienna. The discharge was accordingly given to the President.

With regard to Mr. *J. Jachziel's* report upon the nomenclature of Bitumen, the following resolution was taken. Mr. *Jachziel*, who is to lay the report of Professor *Lunge* (till recently president of Commission Nr. 34) before the Congress, has in his report differed considerably from the report of Professor *Lunge*. It was therefore decided to submit both reports to a fresh resolution of the Committee 34, and to beg Mr. *Clifford Richardson,* Long Island City, N. J., to undertake the presidency. Mr. *Jachziel* is to be invited, to enter the Commission.

Point 8.

Propositions.

With regard to the request of an American Member, that the conditions for life-membership might be settled, the Council decided, that they did not consider the present moment a suitable one for drawing up such a resolution as would require an alteration of the Statutes. The matter was deferred till a later period.

Prof. *Hannover* points out an apparent error in the Methods of testing hydraulic cements recommended by the IVth Congress.

The experiments made in the State Testing Laboratory at Copenhagen have proved that the quantity of 0·4 kilo of cement mentioned in § 3, p. 6 is usually too small to fill the conical metal vessel mentioned in *c*) so that any striking off of superfluous matter with the trowel is impossible. He asks if this fact has been observed by any other experimenter, and should there be any answer in the affirmative, he suggests a slight alteration of this method at the Copenhagen Congress by reducing the size of the vessel.

Prof. *Mesnager* promises to examine into the matter.*)

*) Since then Prof. *Mesnager* has confirmed the observations of Prof. *Hannover.*

Prof. *Hannover* states that the Testing Laboratory of the Danish Artillery has started the question whether Commission 39 dealing with the problem of testing oils could nct extend their studies to such oils and similar substances, such as vaseline in solid form, as may be employed as coating against rust on exposed polished surfaces of machinery.

The Council commissioned the General Secretary to lay the letter in question before Commission 39.

The order of day having been thus exhausted, the *President* thanked all those present for their active participation in the Meeting, and once again for their attending the same in such large numbers.

Mr. *Belelubsky* proposed a vote of thanks from the gentlemen assembled to the President for his able and successful conduct of the Meeting.

Close of the Meeting at 6 p. m.

The Secretary:	The President:
Ernst Reitler.	**Alex. Foss.**

For Membership of the International Association apply:

for GREAT BRITAIN, to Mr. G. C. Lloyd, Secretary of The Iron and Steel Institute, London.

„ THE UNITED STATES OF AMERICA, to Prof. Dr. Edgar Marburg, Secretary of the Am. Soc. Test. Mat., Philadelqhia.

„ AUSTRALIA, to Prof. W. H. Warren, University of Sydney.

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Special notice.

SPECIAL NOTICE.

Number 4 of the Proceedings (English edition) has been completely exhausted. This number contained besides the "Proceedings" of the XVIIIth Council's Meeting dealing with the preparations for the Congress, only the programme of the Vth Congress in Copenhagen and the list of promised reports to be read at the same. As both the programme and the list of reports, corrected and completed, are published in the report of the Congress itself (in Number 14 of the "Proceedings") the former number will not be reprinted.

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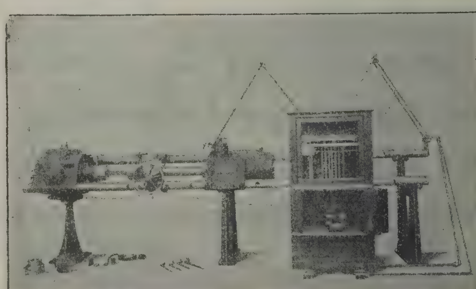

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INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

I1

REPORT ON PROGRESS MADE IN METALLOGRAPHY FROM THE BRUSSELS CONGRESS UP TO THE COMMENCEMENT OF 1909.

By Prof. **E. Heyn**, Groß-Lichterfelde.

Translated from the German by G. Lemmy.

It has become customary to put before the International Association for Testing Materials, among other papers, a report dealing with the development of metallographical research and with its application to every day practice.

Before entering into the subject on the present occasion, we have to record the loss which metallography has suffered through the death of G. Cartaud, the young and talented co-worker with our esteemed member Mr. Osmond. Unmerciful death removed him in September 1906 from a course of scientific work carried out by him and which contained the promise of further successful achievements. Cartaud had given to himself the task of ascertaining more exactly the conditions which intervene in the passage of liquid bodies into the solid state. He put forward the possibility that this transformation did not, of a necessity, lead immediately to crystallisation, but that in many cases, if not in all, there intervened an intermediate stage between the liquid and the solid states, which led to a cellular structure. Then only did crystallisation commence to develop. From this assumption, important deductions may be derived both from the scientific and the practical points of view. Osmond has undertaken to collect together Cartaud's researches in order to bring to a final conclusion the work carried out by the deceased. We may call

attention here to this work, viz: "The researches by G. Cartaud on the passage from the liquid to the solid state". "Rev. Mét." **4**, 819; 1907.

Metallographic research during the period under review has been mainly concerned with the following aims:

a) The fixing the foundations of a Chemistry of intermetallic compounds, by determining the cooling curves of as large a number as possible of alloys, without regard to their practical utility. This object is that followed by Professor Tammann of Göttingen.

b) To further our knowledge of the iron-carbon system. The formation of graphite. The components of hardened steel.

c) To increase our knowledge of special steels and other alloys directly utilisable in technology.

d) The application of metallographic results to actual metallurgical research work, especially to that relating to metals other than iron. The theory of the formation of matte and speiss. This domain is the one taken up by Professor Friedrich, of Freiberg.

e) Improvement in metallographic research in its special bearing upon the testing of materials. Especially the devising of simple processes for controlling the treatment of metals and alloys (heat-treatment, hardening and tempering, degree of cold working and reheating, etc). This branch is dealt with specially by the Königl. Materialprüfungsamt, Groß-Lichterfelde (Heyn and Bauer).

At the present time, it is not a simple matter to issue a short report on the development of Metallography within a given period. Literature dealing with the subject has become so extensive, that in giving even short abstracts on the different classes of work carried out, discrimination has to be used, otherwise there would be practically no limits to this report. It may also occur that some work or other is overlooked, it being difficult to trace everything in data which are divided over a large number of publications. It is, moreover, difficult to draw hard and fast lines between metallography, metallurgy and the allied sciences.

The work carried out has, therefore, been divided into the following main sections, and at the commencement of each section comments of a general nature are made showing the aim the author of the paper had in view.

I. Researches for establishing the chemistry of inter-metallic compounds.

G. Tammann has published in tabular form in the „Zeitschrift des Vereines Deutscher Ingenieure“ 1908, page 1078, data from a series of researches carried out in his laboratory, in which are to be found all the alloys hitherto considered. The "Revue de Métallurgie“ refers also in detail to this work of Tammann, so that we may abstain from entering into consideration of the different binary alloys investigated, especially as we shall refer, in chapters III and IV, to the more important among them from the technical point of view.

Tammann tries, on the basis of the position of metals in the natural system of the elements, to establish rules as regards their faculty of mutually combining together. See on this subject: "Z. anorg. Chemie.“ **49**; 1906: "On the capacity possessed by the elements of combining together“; also **55**; 1907, under the same title.

II. The Iron and Carbon system.

A. Conditions duving solidification.

The first cooling curve dealing with the solidificaton of the iron-carbon system was given by Roberts-Austen in his classical Fourth Report to the Alloys Research Commission, Inst. of Mechanical Engineers. With reference to the starting point of the diagram, that is to say the position of the melting point of carbon-free iron, there had hithertho been some uncertainty, which induced Carpenter to take up this important question. He arrived at the result that the melting point of iron lies between 1505° and 1519° C. ("Iron and Steel Inst.“ 1908, Sept.; "The Freezing-Point of Iron“). At the same time Saklatwalla, in the course of his work in the Technical High School, Charlottenburg, arrived at 1510° C ("Iron and Steel Inst.“ II, 1908).

The question of the separation of graphite from the iron-carbon system has evoked the most lively interest during the period under notice. The view according to which the system iron and graphite is reckoned as stable, and the white graphite-free iron as meta-stable, has established itself more and more. The view has therefore gained ground afresh which had been acknowledged

among practical metallurgists, even before the publication of Roberts-Austen's diagram, but which had been partly shaken by the work carried out by Roberts-Austen in 1897, and more so by the later diagram of Bakhuis-Roozeboom (1900). The theoretical work of Le Chatelier and the conclusive experiments by Charpy and Grenet (1902) showed that the previous view as to the stability of iron-graphite and the instability of white-iron deserved preference. This view, in fact, had been maintained in practical metallurgical circles.

Then Heyn proposed (1904), to represent the solidifying of iron-carbon alloys by a double diagram, one portion showing the meta-stable equilibrium of the graphite-free iron and the other part, the stable equilibrium of the iron-graphite alloy. The diagram was published in the "Zeitschrift für Elektrochemie" 1904 ("Stable and meta-stable equilibrium of iron-carbon alloys"). Charpy one year later, and independently of Heyn, published a double diagram which, apart from a few unimportant deviations, corresponds with Heyn's diagram. The Heyn-Charpy double diagram has the advantage that it separates in a clearer manner the stable occurrences from the meta-stable, and gives in a simple way a clear survey of the whole conditions. For these reasons, it has been adopted by most specialists engaged in research work; there is, it is true, a tendency to use it under other appellations, and small changes of no fundamental importance have been made, the principle underlying the diagram being forgotten. There is also a tendency to trace back to certain individualities the opinion that the graphite-iron system is the more stable and the white iron the less stable, and this in the view of the author is hardly possible; at all events one does not go in this matter, and from the historical point of view, sufficiently far back into the past.

Attempts have been made in various quarters, and, among others, by Charpy (see Literature list below, no 5) and by Benedicks (see no 1), to trace in the diagram the solubility of graphite in iron down to temperatures of 800° C. In doing this, Benedicks relies essentially upon the coincidence that exists between the percentage of graphite which separates at a given temperature, according to researches made by Charpy, and the percentage of carbon absorbed in cementation according to work carried out by R. Mannesmann. Although no more doubt is entertained with regard

to the solubility of graphite in iron, its quantitative determination, as fixed by Benedicks, does not as yet appear to me quite reliable, for there is room for chance in the matter. Consideration should be given to the question as to whether in the cementation process one has to deal with the iron-carbon system per se, and not rather with the three component system, viz: iron-carbon-nitrogen, in which other equilibrium relations intervene; and if this were solved, many points, still doubtful, would be cleared up.

It is probable that those portions of the double diagram which relate to the solidification of the iron-graphite system are in the main only exceptionally determinable, and that iron, even when high in silicon, first solidifies graphite-free, persisting therefore in the undercooled state. Undercooling is generally got rid of only immediately after freezing. Experimental illustrations on this point have been put forward by Heyn and Bauer (see no 12). They chilled iron-carbon melts at various temperatures above and below the freezing point and ascertained the percentage of graphite in them; later on, Goerens and Gutowsky (see no 8) made experiments in the same direction and by exactly the same method, which led to the same results.

The works which deal with the freezing of the iron-carbon system are the following, arranged alphabetically according to the authors names:

1. Benedicks: "On the state of equilibrium and the freezing of iron-carbon alloys". "Metallurgie" **3**, 393, 425, 466; 1906.

2. Benedicks: "On the solubility of graphite in iron". "Metallurgie" **5**, 41; 1908.

3. Charpy: "On the identity of graphite and temper-carbon in cast-iron". „Rev. Métallurgie" **5**, 75; 1908.

4. Charpy: "On the solubility of graphite in iron". "Same review" **5**, 77; 1908.

5. Charpy: "On iron and carbon alloys". "Proceedings of the Soc. Chimique de France", 1908.

6. Gahl: "Information on the graphite separation in iron-carbon melts with high percentages of carbon". "Stahl und Eisen" 225; 1908.

7. Goerens: "On the present standpoint of our knowledge as regards freezing and conversion phenomena in the case of iron-carbon alloys". "Metallurgie" **3**, 175; 1906 and **4**, 137; 1907.

8. Goerens and Gutowsky: "Experimental researches on the freezing and fusion phenomena of cast-iron". "Metallurgie" 5 137; 1908.

9. Goerens and Stadeler: "On the influence of chromium on the capacity of iron for dissolving carbon, and on the graphite formation". "Metallurgie" 4, 18; 1907.

10. Gutowsky: "Experimental research on the freezing and fusion phenomena of technical cast-iron (phosphoric cast-iron"). "Metallurgie" 5, 463; 1908.

11. Heyn: "Metallographic researches for foundry practice". "Stahl und Eisen" 1295 and 1386; 1906.

12. Heyn and Bauer: "On the metallography of cast-iron". "Stahl und Eisen" 1568 and 1621; 1907

13. Howe: "The carbon-iron diagram". "Trans. Amer. Inst. Min. Eng." 1908.

14. Portevin: "Present position of the theories on the equilibrium curve of the iron-carbon system". "Rev. Métallurgie" 4, 993; 1907 and 5, 24; 1908.

15. Sauveur: "The constitution of iron-carbon alloys". "Journ. Iron and Steel Institute" 1906, IV, 493.

16. Thomas Turner: "Volume and Temperature changes during the cooling of cast-iron". "Journ. Iron and Steel Institute" 1906, I, 48.

17. Wüst: "On the dependence of the separation of graphite upon the presence of foreign elements in cast-iron". "Metallurgie" 3, 169; 1906.

18. Wüst: "Contribution to the theory of graphite formation". "Metallurgie" 3, 757; 1906.

19. Wüst and Petersen: "Note on the influence of silicon on the iron-carbon system". "Metallurgie" 3, 811; 1906.

20. Wedding and Cremer: "Chemical and Metallographical research on chilled cast iron". "Stahl und Eisen" 1907, 833 and 866.

An important work, which, although it does not directly belong to this group, may offer a valuable foundation for further researches is:

21. Le Chatelier and Wologdin: "On the density of graphite". "Rev. Métallurgie" 5, 140; 1908.

B. On the conduct of the iron-carbon system after freezing. Thermal and Mechanical treatment.

With regard to the ascertaining of the critical points A_1 and A_2 in iron by measuring the electrical resistance, this is dealt with in a publication by Osmond: "Fournel's researches and the lower limit of point A_2". "Rev. Métallurgie" **3**, 551; 1906.

During the period under review, the question as to the nature of the constituents Troostite, Sorbite and Austenite has been dealt with in detail. As having worked on the former question, may be mentioned: Heyn and Bauer "On the internal structure of hardened and tempered tool-steel". "Mitteilungen des Kgl. Materialprüfungsamt", Groß-Lichterfelde, 1906; page 29. See also Osmond: "The researches of Prof. Heyn on the hardening and tempering of steel, Results and Deductions". "Rev. Métallurgie" **3**, 621; 1906. Howe: "A new iron-carbon phase, Osmondite". "Electrochem. and Met. Industry" **5** no 9; page 347.

From the work of Heyn and Bauer, the following is derived, on the basis of solubility researches and of a series of physical constants obtained by Barus and Strouhal on hardened and tempered steel using eutectic steel with about 1 per cent carbon.

The transition from hardened steel (Martensite), to annealed steel (Pearlite) does not take place directly, but through a well-defined meta-stable intermediate form, which, with a view to honour Osmond, was called Osmondite and which marks the limit between Troostite and Sorbite. On tempering, Martensite first changes into Troostite which on the temperature increasing, approaches the Osmondite constituent (at a tempering heat of about 400^0 C.) On the tempering heat further increasing there occurs a transition from Osmondite to Sorbite and finally into Pearlite. Osmondite is characterised by a very great solubility in dilute sulphuric acid, and, further, by acquiring a very dark tint on etching with alcoholic hydrochloric acid (1 per cent). On the other hand, Troostite emits, on dissolving out of contact with the air in a ten per cent sulphuric acid solution, gaseous carburetted hydrogen, the carbon of wich is styled C_h, there remaining besides a residue whose percentage of carbon is insoluble in hot concentrated hydrochloric acid, and which is styled C_f. This residue cannot be carbide as this dissolves completely in hot, concentrated, hydrochloric

acid, emitting carburetted hydrogen gas. Therefore the form of carbon contained in Troostite is different from the carbide carbon C_c. The carbide which is characterised by the fact that it is insoluble in a 10 per cent solution of sulphuric acid out of contact with the air, but is soluble in hot, concentrated, hydrochloric acid, first makes its appearance on tempering at about 400^0 C., therefore as the structure approaches Osmondite, after which it increases very rapidly with the increase in the tempering temperature. The amount of C_f augments from Martensite to Osmondite, subsequently decreasing.

The second result of the work in question is that each quenching is equivalent in its effect to an ideal under-cooling of steel down to pure Martensite, together with a subsequent more or less energetic tempering. The extent of the latter depends upon the speed of quenching. This explains the occurrence of Troostite and Osmondite in quenched steel and that of Sorbite in annealed, but comparatively rapidly cooled steels. If the pure Martensite be designed as steel of tempering degree 0, giving to annealed steel the tempering degree 1, every annealing temperature would correspond to a tempering degree lying between 0 and 1. A quenched steel does not always require to have the tempering degree 0; its tempering degree, according to the speed of cooling, may be nearer 1, even when an intended tempering has not taken place at all.

In his work entitled: "Experimental researches on the cooling power of liquids; on quenching velocities"; "Iron and Steel Institute" II, 153, 1908, Benedicks maintains his former hypothesis to the effect that Troostite is a colloidal solution of cementite in iron, therefore a Pearlite with ultra-microscopically separated particles of Cementite. He endeavours to bring in harmony with his hypothesis the observations made by Heyn and Bauer.

At the meting of the Iron and Steel Institute last May, Heyn and Bauer read a paper on the influence of the prior treatment of steel on its solubility with respect to sulphuric acid; and the possibility, from the observed solubility, of drawing conclusions regarding the prior treatment of the material. In this paper the authors again return to the above question and emphasise the point that the hypothesis of Benedicks — as every other hypothesis — is acceptable, provided that it will prove its fertility. From experiments made as to the emission of heat during the tempering of hardened steel, the

authors showed that the main quantity of heat is actually freed up to 400⁰ C. From this it can be concluded that up to 400⁰ C., therefore during the conversion of Martensite through Troostite to Osmondite, one or more X bodies separate. The quantity of heat set free on the transformation from Osmondite to Pearlite can only be small. It is not possible to say anything in regard to the nature of this X body. There is, above all, no proof at hand that it is cementite. On the contrary, the behaviour of Troostite and Osmondite — both of which must contain the X bodies — with respect to the ten per cent solution of sulphuric acid out of contact with the air and to the after treatment of the residue obtained with hot concentrated hydrochloric acid, speaks against this. For as above remarked, Troostite and Osmondite yield C_h and C_f but no C_c.

There appeared in "Rev. de Métallurgie", **5**, 711; 1908, a paper by E. Maurer, "Experiments on the quenching and annealing of Iron and Steel". Maurer finds, among other points, that the specific gravity of quenched and tempered steel in the vicinity of Osmondite shows a maximum, so that on the conversion from Martensite to Osmondite, through Troostite, a decrease in volume takes place, while the change over from Osmondite to Pearlite is accompanied by expansion. Further, Maurer establishes a remarkable irregularity in the curves of residual magnetism as dependent on the tempering temperature, in the neighbourhood of Osmondite. It is in this respect that opportunity is afforded the Benedicks hypothesis to show its fertility by explaining the point.

Heyn and Bauer mention in their paper to the Iron and Steel Institute that even with a very low carbon steel a dissolution curve quite similar to that with eutectic steel is obtained on quenching and on tempering at rising temperatures. Here also a distinct maximum of solubility in the proximity to Osmondite is apparent at a temperature somewhat below 400⁰ C. From this it may be asked what action does allotropy of iron play in tempering? It is not simply a question concerning the X body which separates up to the formation of Osmondite, but also as to what takes place in the remaining mass in which X is embedded. There appears to be here another field open for research, and one must not be satisfied with Benedicks' hypothesis until all doubt is set aside as to whether there can intervene no meta-stable intermediate phases between Martensite and Pearlite. For the present there is

much justification for doubt. There are more facts which speak in favour of the existence of such meta-stable intermediate phases, than to the contrary. Finally, stress must be laid upon the fact that the conversion from an unstable equilibrium to a stable one takes place in the majority of cases through a meta-stable one. The view taken by Heyn and Bauer includes therefore more facts than are covered by that of Benedicks.

In the paper above referred to, Benedicks describes very interesting discoveries as to the nature of Austenite. From these, it appears that Austenite can only remain as such during quenching, if sufficient pressure is available. For this reason, Austenite does not come to the surface of hardened steel, but occurs internally. Benedicks adds an experiment in which after grinding the outside surface of hardened steel by which operation the pressure on the remaining portion is relieved, the Austenite previously contained in is converted into Martensite.

Maurer also has gone fully into the question of Austenite in his work already mentioned. He has found that the presence of manganese in the steel promotes the maintenance of Austenite on quenching. In steel having a very low percentage of manganese, Austenite is converted into Troostite at from 150° C. to 250° C. on tempering.

Benedicks has also carried out valuable experiments on the quenching velocity of steel in different liquids. He has come to the conclusion that the cooling capacity of a liquid is to a great extent conditional upon 1st a high heat of vaporisation; and 2nd so low a temperature that the steam-bubbles formed on the top of the surface of the metal can easily be condensed by the surrounding liquid. The speed at which the liquid moves exerts but little influence. Reference can be made to his paper for further very interesting data.

Work on hardened steel has been carried out by Breuil: "Researches on the constituents of hardened steel". ("Bullet. de la Soc. de l'Ind. Min." **6**; 1907 and by Kurbatow: "Contribution to the metallographic study of hardened steels." (Rev. Métallurgie **5**, 704; 1908).

Campbell gives a series of valuable papers on the influence of thermic treatment on steel. (Metallurgie, **3**, 741, 781; 1906 and **4**, 772, 881; 1907.)

In their work above referred to on: "The relation of the solubility of iron and Steel in sulphuric acid to its heat treatment", Heyn and Bauer indicate the field in which quantitative research with $^1/_{100}$ dilute sulphuric acid can be applied. The solubility of steel arrived at by measuring the loss in weight is a function of the pre-treatment and affords evidence as to the following matters:

a) The ascertaining of the degree of tempering of hardened, or of hardened and tempered steels;

b) The ascertaining of the temperature at which tungsten-chrome steel has been quenchèd. The solubility test affords in this quality of steel (which belongs to the high-speed steel class), better information than micrography.

c) The ascertaining of the degree of cold working which steel has undergone. In this, the solubility of the metal is of extraordinary efficient service. By its means it is possible to find out whether a steel has received permanent stretch or com pression at ordinary temperatures, even when the extent of such permanent set amounts to only $2^0/_0$. This is of importance when one considers the frequently recurring question as to whether a part of a structure has been tasked beyond the limit.

d) The ascertaining of the temperature up to which a steel worked in the cold has been reheated.

III. Iron and manganese alloys.

1. Special classes of steel: The study of these has also made much progress during the time under review, owing to the extensive and interesting work carried out by Guillet: "Quarternary steels", "Iron and Steel Inst." II, 1; 1906. — "Nickel-Chrome-Steel", "Rev. Mét." **3**, 462; 1906. — "Nickel-Silicon-Steel", same "Review", p. 621. — "Chrome-Tungsten-Steel", "Rev. Mét." **4**, 5; 1907. — "Vanadium-Steel", same "Review", p. 775. — "Boron-Steels", same "Review", p. 784. — "Chrome-Steel", same "Review", p. 1025.

Amongst other work may be mentioned: "Copper-Steels", by Breuil, "Iron and Steel Inst." II, 1; 1907. — "Tungsten-Steels", by Swinden, same "Proceedings" I, 291; 1907.

2. Iron and Sulphur: Treitschke and Tammann. „Z. anorg. Chem.“ **49**, 320; 1906. There exists but a limited solubility between iron and iron-sulphide in the liquid state. Mixed crystals with a small percentage of the second body separate out both on the side of the iron and on that of the sulphide. We get the eutectic with 85% FeS and 15 Fe, and at a temperature of 970° C. The temperature of conversion of the Gamma iron into Beta iron is lowered by the presence of iron-sulphide. With about 10 per cent FeS the the transformation of Gamma to Beta iron coincides with that of Beta to Alpha iron. At 128° C. the iron sulphide it selfundergoes a transformation accompanied by a large increase in volume.

A valuable extension of the above work is afforded by Levy's researches: “Iron, Carbon and Sulphur“, “Iron and Steel Institute“ II, 1908.

3. Iron and Phosphorus: A thorough study of this has been given by Saklatwalla (Doctorate work), Berlin Technical High School; also published in “Iron and Steel Institute“ II, 92; 1908. Two combinations are pointed out, Fe_3P and Fe_2P. Up to 1,7 phosphorus (see Stead: “Iron and Steel Institute“ Sept. 1900), there exist mixed crystals; from that point downwards the mixed crystals form with Fe_3P and Fe_2P a freezing diagram with an eutectic at 1000° C. containing 10.2 per cent of phosphorus. The system Fe_3P and Fe_2P also forms an eutectic at 16.2 per cent phosphorus and 960° C.

Gercke (“Metallurgie“ **5**, 604; 1908) removes a few discrepancies which occur in Saklatwalla's diagram. He finds the eutectic of mixed crystals and the combination Fe_3P (10.2 per cent P) at 980° C., instead of 1000° C., and explains the irregularities in the course of Saklatwalla's eutectic line by the phenomenon of undercooling.

Iron, Carbon and Phosphorus. This system is studied by Wüst, “Metallurgie“ 5, 73; 1908. He found the three component eutectic at 950° C, with composition corresponding to 2 per cent carbon, 6.7 per cent phosphorus and 91.3 per cent iron. Goerens and Dobblestein have also published papers on the same system. “Metallurgie“ 5, 561; 1908.

4. Iron, Carbon and Silicon. In extension of the work by Guertler and Tammann on iron and silicon („Z. anorg.

Chem." **47**, 163; 1905), Gontermann has studied more closely the Fe + C + Si. System („Z. anorg. Chem." **59**, 373; 1908). His work cannot be given in abstract and reference must be had to it direct.

5. Iron and Chromium. Treitschke and Tammann. „Z. anorg. Chem." **55**, 402; 1907.

6. Iron and Copper. Sahmen. „Z. anorg. Chem." **57**, 9; 1908.

7. Iron and Molybdenum. Lautsch and Tammann. „Z. anorg. Chem." **55**, 386; 1907. The conditions which rule in this important system have not been made clear, so far, to a sufficient extent to permit of a brief exposition.

8. Iron and Tantallum. Guillet. "Comptes-rendus" **145**, 327; 1907.

9. Iron and Vanadium. Pütz. "Metallurgie" **3**, 635; 1906.

10. Iron and Tungsten. Harkort. "Metallurgie" **4**, 617, 639, **6**, 73; 1907.

11. Iron and Zinc. Wologdin. "Rev. Mét." **3**, 701; 1906.

12. Manganese and Carbon. Stadeler. "Metallurgie" **5**, 260; 1908.

13. Manganese and Silicon. Doernickel. „Z. anorg. Chem." **50**, 117; 1906. The combinations Mn_2Si and MnSi are derived from the fusion curve.

IV. Alloys of metals, apart from iron, important in technology.

Guillet has published a very complete work in the "Rev. Mét." **3**, 155; 1906 entitled: "Later researches on industrial alloys and their importance", also in the same review, **3**, 243; 1906: „General survey of the special brasses"; and still in the same review, **4**, 622; 1907: "Researches on the constitution of copper alloys".

A. Copper Alloys.

1. Copper and aluminium. The eighth report of the Alloys Commission, Institute of Mechanical Engineers, by Carpenter and Edwards ("Proc. Inst. Mech. Eng." 1907, p. 57) deals with this series of alloys. The work is thorough in every respect; its contents form a most valuable addition to our metallographical

and metallurgical knowledge. One notices in it the efforts made by the authors to make their research complete from start to finish, a point on which emphasis should be laid, as the same cannot be said of various other workers in the domain of metallography.

2. Copper and Manganese. Wologdin. "Rev. Met." **4**, 25; 1907. Sahnen. "Z. anorg. Chem." **57**, 20; 1908.

3. Copper and Magnesium. Sahnen. "Z. anorg. Chem." **57**, 26; 1908.

4. Copper and Nickel. Guertler and Tamman. "Z. anorg. Chem." **52**, 25; 1907. Kurnakow and Żemczużny. "Z. anorg. Chem." **54**, 149; 1907.

5. Copper, Nickel and Zinc. Tafel. "Metallurgie" **5**, 343; 1908.

6. Copper and Phosphorus. Heyn and Bauer. "Mitt. Kgl. Materialprüfungsamt", Groß-Lichterfelde, 1907, 6th issue.

7. Copper and Sulphur. Heyn and Bauer. "Metallurgie" **3**, 73; 1906.

8. Copper, Sulphur, Selenium and Tellurium. Hinrichsen and Bauer. "Mitt. Kgl. Materialprüfungsamt", Groß-Lichterfelde, 1907, 6th issue. A theoretical explanation is added to the description of the very delicate qualitative identification of sulphur, selenium and tellurium in copper alloys in the work (no 7).

9. Copper and Tellurium. Chiskashige. "Z. anorg. Chem." **54**, 50; 1907.

10. Copper and Silicon. Rudolfi. "Z. anorg. Chem." **53**, 216; 1907. Philips. "Metallurgie" **4**, 587; 1907. Guertler. "Metallurgie" **5**, 185; 1908.

11. Copper and Selenium. Friedrich and Leroux. "Metallurgie" **5**, 355; 1908.

12. Copper and Bismuth. Jeriomin. "Z. anorg. Chem." **55**, 412; 1907.

B. Aluminium Alloys.

13. Aluminium and Magnesium. Longuinine and Shukareff. "Rev. Mét." **3**, 48; 1906.

C. Nickel Alloys.

14. Nickel and Carbon. Wilms. (Doctorate work.) Techn. High School Berlin.

D. Lead Alloys.

15. Lead and Antimony. Gontermann. "Z. anorg. Chem." **55**, 419; 1907.

16. Lead, Magnesium and Tin. Vegesack. "Z. anorg. Chem." **54**, 367; 1907.

17. Lead and Tin. Rosenhain and Tucker. "Trans. Roy. Soc. London" A. **209**, 89; 1908. This work offers special interest by the detection of a transformation below the eutectic temperature which had escaped former observers.

E. Metals and Gases.

18. On the occlusion and diffusion of gases in metals: Sieverts' paper on his appointment as lecturer, Leipzig. 1907.

V. Metallographical Investigation of Phenomena in the Manufacture of Metals other than Iron. Matte and Speiss.

Most of the researches published under this heading proceed from Prof. Friedrichs's Laboratory, School of Mines, Freiberg (Saxony). The following is a list of some of these publications:

1. Lead and Arsenic. Friedrich. "Metallurgie" **3**, 41; 1906
2. Silver and Arsenic. Friedrich and Leroux "Metallurgie" **3**, 192; 1906.
3. Silver and Silver-sulphide. Friedrich and Leroux. "Met." **3**, 361; 1906.
4. Lead and Silver. Friedrich. "Metallurgie" **3**, 396; 1906.
5. Zinc and Arsenic. Friedrich and Leroux. "Met." **3**, 477; 1906.
6. "Concerning the Copper-Matte". Röntgen. "Met." **3**, 479; 1906.
7. Lead matte. Weidmann. "Metallurgie" **3**, 660; 1906.
8. Iron and Arsenic. Friedrich. "Metallurgie" **4**, 129; 1907.
9. Nickel and Arsenic. Friedrich. "Metallurgie" **4**, 200; 1907.
10. Copper, Silver, Lead. Friedrich and Leroux. "Met." **4**, 293; 1907.
11. The fusion curves of the binary system, lead sulphide-magnetic pyrite and lead suphide-silver sulphide. Friedrich. "Metallurgie" **4**, 479; 1907.

12. The fusion curves of the binary systems, silver sulphide-copper sulphide and lead sulphide-copper sulphide. Friedrich. "Metallurgie" **4**, 671; 1907.

13. The fusion curves of the Nickel-sulphide compounds. Bornemann. "Metallurgie" **5**, 13; 1908.

14. Contribution to the knowledge of the metallic sulphides PbS, Cu_2S, Ag_2S, FeS. Friedrich. "Metallurgie" **5**, 23 and 50; 1908.

15. On the constition of Nickel-Matt. Bornemann. "Metallurgie" **5**, 61; 1908.

16. Zincblende as a matte constituent. Friedrich. "Metallurgie" **5**, 114, 1908.

17. On the fusion curves of the binary systems, platinum-arsenic and bismuth-arsenic. Friedrich and Leroux. "Metallurgie" **5**, 150; 1908.

18. Fusion curve of the cobalt-arsenic alloys. Friedrich. "Metallurgie" **5**, 150; 1908.

19. Fusion curve of the cobalt-sulphur alloys. Friedrich. "Metallurgie" **5**, 212; 1908.

20. New researches on the fusion curve of the copper arsenic alloys and the electrical conductivity resistance of copper containing arsenic. Friedrich. "Metallurgie" **5**, 529; 1908.

21. The smelting of copper ores in shaft-furnaces. Baikow. "Mitt. des Petersburger Polyt. Inst." **9**; 1908.

VI. General data on the phase theory, equilibrium diagrams, physico-chemical methods in aid of metallography. Crystallography.

A. Crystallography.

1. In the first place reference should be made to a research by Osmond and Cartaud: "The crystallography of iron". "Iron and Steel Institute" II. 522. 1906. In this the various phases in the deformation of iron crystals are completely investigated.

2. "Deformation and fracture in iron and steel". Rosenhain. "Iron and Steel Institute" II. 189; 1906.

3. "Crystallisation and Structure of steel". Baikow. "Mitt. des Petersburger Polyt. Inst." **8**, 289; 1907.

B. Hardness.

4. "The Hardness of the constituents of iron and steel". Boynton. "Iron and Steel Inst." II. 287; **1906**.

5. "Hardness of metallic solid solutions and of certain chemical combinations". Kurnakow and Żemczużny. "Z. anorg. Chem." **60**, 1; 1908.

C. Expansion through heat; specific heat; heat of fusion.

6. "The heating of copper with special reference to expansion". Turner and Levy. "Proc. Roy. Soc. London" A. **80**; 1907.

7. "Specific heat of the iron carbon alloys". Oberhoffer and Meuthen. "Metallurgie" **5**, 173; 1908.

8. "The latent heat of fusion of pure iron". Brisker. "Metallurgie" **5**, 183; 1908.

9. "On the quantity of heat of binary systems". Tammann. "Z. phys. Chem." **64**, 357; 1908.

D. Fusion and transformation curves.

10. "On the variation in the melting point of eutectic mixtures". Benedicks and Arpi. "Metallurgie" **4**, 416; 1907.

11. "On the form of the fusion curves in binary systems and on the dissociation of compounds in equilibrium, etc." Ruer. "Z. phys. Chem." **59**, 1; 1907 and also **64**, 357; 1908. To the three types of Bakhuis-Roozeboom having complete mutual solubility in the liquid and solid state, a fourth type is added, which, like types II and III has a horizontal tangent in the concentration-temperature diagram, but no minimum or maximum. According to the author, the systems Bromine-Iodine and Magnesium-Cadmium belong to this type. Further, the author points out, on the basis of thermo-dynamic observations, that in binary systems of components able to form chemical combinations, the fusion curve does not give a point but a rounding off in the regions corresponding to the separation of a compound. Laar is opponent of the manner in which Ruer endeavours to give the proof of this phenomenon. "Z. phys. Chem." **66**, 197; 1909. Fusion curves of binary systems.

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13. “Remarks on recalescence curves“. Rosenhain. “Proc. Phys. Soc. London“ **21**; 1908.

14. “On the methods for determining cooling curves“. Burgess. „Bull. Bureau of Standards“ **5**; 1908.

E. Electromotive force. Conductivity.

15. “Potential and nature of metallic alloys“. Pushin. Petersburg. 1906.

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17. “On the electric conductivity of alloys“. 1. “Connection between conductivity and constitution“. 2. “Connection between constitution and the temperature coefficient of conductivity“. Guertler. “Z. anorg. Chem.“ **51**, 397; 1906 and **54**, 58; 1907.

18. “Remarks on Matthiessen’s law concerning the temperature coefficient of electric conductivity in metallic alloys“. Guertler. “Physikalische Zeitschrift“ **9**, 29; 1907.

19. “On the electric conductivity of alloys and their temperature coefficients“. Guertler. “Physikalische Zeitschr.“ **9**, 404; 1908.

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VII. Accessories for metallographic work.

A. Etching reagents.

1. “Rapidity of attack by metallographic reagents“. Lejeune. “Rev. Métallurgie“ **3**, 426; 1906.

2. “Etching reagents for the metallographic study of steel“. Kurbatow. “Rev. Métallurgie“ **3**, 648; 1906.

B. Optics. Photography.

3. “On an apparatus for ascertaining and measuring optical anisotropy of opaque substances and its use“. Königsberger. „Zentralblatt für Mineralogie etc.“ **1908**, p. **565**.

4. "Microscopy in ultra-violet rays". "Short contributions on metallographical and metallurgical subjects". Friedrich. "Metallurgie" **5**, 593; 1908.

5. "Colour photography in metallography". Révillon and Beauverie. "Rev. Métallurgie" **5**, 885; 1908.

6. "On the application of Lumière colour photography to metallography". Goerens. "Metallurgie" **5**, 19; 1908.

C. Apparatus for determining the melting point and point of arrest.

7. "Remarks on the use of the differential galvanometer". Portevin. "Rev. Métallurgie" **5**, 295; 1908.

8. "Recording pyrometer with fixed photographic plate". Wologdin. "Rev. Métallurgie" **4**, 552; 1907.

D. Furnaces.

9. "A double-muffle-gas-assay furnace for studying the heat treatment of steel". Howe. "Proc. Amer. Soc. Test. Materials" **6**, 202; 1906.

10. "On a gas crucible furnace for metallographic researches". Friedrich. "Metallurgie" 3, 206; 1906.

VIII. Application of metallography to practical industry.

It is now fully admitted that metallographical research has become absolutely necessary in the matter of testing materials, and metallographic processes have found their way into the laboratories attached to metallurgical works. The writer is not informed as to the conditions which rule on this point outside of Germany. As regards Germany, it may be observed that apart from the private individuals who have been instructed in the Königl. Materialprüfungsamt there have been, counting from 1904 only,

31 students sent by large works,
11 „ „ „ high schools,
2 „ „ „ other schools,
1 „ „ „ a testing etablishment.

From this statement an opinion can be formed as to the interest which has been excited in industrial and other practical circles, especially when it is remembered that instruction in this branch has now been given for some considerable time at five

high schools, the Materialprüfungsamt only affording short periods of instruction to engineers in case of necessity, teaching not being one of its special functions.

Among the papers dealing specially with the application of metallography to practical work, may be stated:

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Hoitsema. "Metallography as an aid in detecting base coins". "Metallurgie" **3**, 128; 1906.

Heyn. "Data on metallographic practice". "Stahl und Eisen" 1906, Nr. 1.

Heyn. "On the application of metallography in the iron industry". "Stahl und Eisen" 1906, Nr. 10.

Heyn. "Metallographical research in foundry work". "Stahl und Eisen" 1906, Nr. 21 and 22.

Heyn. "Report on etching methodes for macroscopical research into the texture of malleable iron, and the results derived therefrom". „Mitt. Königl. Materialprüfungsamt", Groß-Lichterfelde 1906, p. 253.

Bannister. "The relation between type of fracture and the microstructure of steel test pieces". Iron and Steel Inst. 1906, I. 161.

Guillet. "The utilisation of microscopic metallography in practical work". "Génie Civil", June 1907.

Sauveur. "The application of metallography to foundry practice". "Foundry" Jan. and April 1907.

Heyn. "On permanent strains due to cooling". "Stahl und Eisen", Sept. 1907.

Boyer. "Microscopic metallography and its employment in French Industries". "Engineering Magazine" 1909, p. 664.

IX. Text books on metallography.

An excellent book, which will be found specially valuable by all who desire to study the states of equilibrium of metal solutions, is that by Ruer: entitled "Metallographie in elementarer Darstellung", Leipzig und Hamburg, Leopold Voss, 1907.

An elementary work on Metallography, its Processes and Applications has been written by Heyn and Bauer, and is published at the Göschensche Verlagsbuchhandlung, Leipzig 1909.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

I2

SPECIAL STEELS.

By **Léon Guillet**, Paris.

Translated from the French by Dr. H. Borns, London.

Since the last Congress, held at Brussels, the manufacture of special steels has made interesting progress and has taken a perfectly definite course which it may be instructive to indicate.

It is the actual tendencies which we wish to discuss briefly.

We may remark at the outset that, if we class steels according to their structure, as we have done in the memoir presented to the last Congress, we see that at present perlitic steels (those which display the same structure as ordinary carbon steels) are almost the only ones which are used as materials of construction.

It is certain in fact, that the polyhedric steels (gamma iron-steels containing much nickel and manganese) are losing every day in commercial importance, on account both of their high price and of their low elastic limit. They are indeed hardly applied except in very particular cases, when their high resistance to oxidation, their capability of withstanding the temperatures of superheated steam, or finally the expansion coefficients characteristic of some of them are to be utilised. But their application in mechanical construction, on which certain metallurgists placed great hopes, has not become general.

The Hadfield steel always finds interesting appreciation in cases, where high resistance to shocks and to wear must be allied.

Disregarding tool steels and steels for balls and ball-bearings of carbide structure we only find one industrial kind of steel now: the perlitic steels.

Let us enquire into the actual tendencies in the manufacture of these products.

The special perlitic steels, approximately arranged as to their importance, are:

The nickel steels and the nickel-chrome steels.

The vanadium steels, with or without nickel and chromium.

The silicon steels (often called mangano-silicon steels.)

Finally, more rarely, the tungsten steels.

Whichever steels may be considered, the actual tendencies are the following:

1. Raising the mechanical strengths, such as we are accustomed to define them; in this respect the introduction of vanadium is especially to be mentioned, but it is little utilised in Europe.

2. The simplification of the thermal treatment.

3. The creation of special types for parts exposed to friction.

In attempting to raise the mechanical strength, that is to say, to produce steels characterised by the highest breaking strength and the highest elastic limit without being too fragile, we have been led to the production of more and more complex steels, containing often three elements which are foreign to ordinary steel. We have in this question to distinguish two important points:

The steels which give interesting values, when rough forged or better when annealed, suffer from a grave disadvantage; if they possess high elastic limits, they are very difficult to machine.

Those steels on the contrary which, in the annealed condition, have medium mechanical strength and which, by an approriate, sometimes very simple thermal treatment, can be trans formed into high-strength steels, offer a very great interest because worked in the annealed state, they do not require more than a tempering after the treatment.

Let us look at the extreme values which we can obtain.

Some time ago I described a nickel-silicon steel which gave extraordinary values. The composition was:

C = 0·221, Ni = 12·00, Si = 1·78, Mn = 0·112, S = 0·011, P = 0·005.

Annealed at 900° it yielded the following figures: R[1]) = 170·0, E[2]) = 141·1, A[3]) percent = 9, Σ[4]) = 42·9, impact = 5.

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[1]) R = Strength, [2]) E = Elastic limit, [3]) A = Elongation, [4]) Σ = Elongation + Contraction.

After hardening at 825° in water of 20°: R = 202 8, E = 138·3, A per cent = 4, Σ = 0, impact = 10.

But this steel is as such martensitic, very difficult to work without treatment. We do not believe that it has any industrial future.

There are some other industrial types belonging to the category of steels which, in their normal conditions, are easy to manage and which, by suitable treatment, acquire noteworthy properties.

1. Nickel-Vanadium Steels.

Composition: C = 200, Ni = 7, V = 0·2, Mn = 0·30.

Properties when annealed: R = 65, E = 45, A = 20 per cent.

Properties after hardening at 850° C. in water: R = 140, E = 120, A = 10 per cent.

2. Nickel-Chrome-Vanadium Steels.

Composition: C = 0·450, Ni = 2·25, Cr = 0·60, V = 0·07, Mn = 0·28.

Properties when annealed: R = 70, E = 50, A = 20 per cent, impact = 6.

Properties after hardening at 800° and tempering at 400°: R = 150, E = 130, A = 6 per cent, impact = 11.

It will be noted that the resistance to shock is greater after hardening than before hardening.

3. Nickel-Chrome Steels.

Composition: C = 0·173, Ni = 5·47, Cr = 0·18, Mn = 0·55, Si = 0·16.

Properties when annealed: R = 61, E = 36, A = 21·5 per cent, Σ = 55, impact = 12.

Properties after hardening at 850° in oil: R = 130, E = 122, A = 5 per cent, Σ = 15, impact = 11.

We see that we may safely rely on a strength of 140 or 150 kg per mm^2 and an elastic limit of 120 kg per mm^2, accompanied by a resistance to shocks of 10 or 12 kgm; these figures characterise a steel which would not be fragile for a large number of applications (shafting, gearing).

There is one tendency which has become extraordinarily general during the last months; it is the introduction of vanadium into steels.

We have dwelt in several communications on the important part played by vanadium; this element augments the properties which we produce by quenching to a very considerable degree.

0·2 or 0·3 per cent of vanadium suffice to raise the breaking strength and the elastic limit after quenching considerably, without sensibly modifying the properties of the annealed metal. Chromium and silicon act in the same sense; but they also introduce fragility and they modify the properties of the annealed metal much more than vanadium does.

It should also be pointed out that vanadium has received much more attention in England and particularly in America than in France. Very satisfactory results have been realised in the production of armour plates, springs, matrices etc., and vanadium steels are quite an industrial product.

The second point aimed at in the improvement of the manufacture of special steels concerns the simplification of the thermal treatment. This is a most important feature. Most works are not equipped for a precise treatment which comprises quenching at a definite temperature and tempering at some precise temperature, considering that the latter process has to be carried out as a rule at low temperatures ranging from 200 to 400^0, and that a variation of 25^0 will often materially alter the properties especially as regards friction.

Metallurgists have therefore had every reason to simplify the thermal treatment which is to impart certain qualities to the steel.

The first step taken in this direction has been the suppression of the tempering process.

With this object in view attempts have been made to vary the composition of the steel in such a manner that the brittleness after quenching — desirable for some applications — should not erquire subsequent diminution by some tempering process.

The nickel-vanadium steel of which we have already spoken is a notable example in point. It is quenched in water, and we need not much trouble about the exact temperature of the water.

With the same object have been produced steels containing slight percentages of nickel-manganese and silicon, but rather rich in carbon; these steels need a simple quenching in oil, at 800 or 900^0. ($C = 0·45$, $Ni = 1·25$, $Mn = 1·14$, $Si = 1·28$.)

It is however, quite obvious that, of all treatments, ordinary air-cooling is undoubtedly the simplest. Leaving the rapid tool-steels, with which we do not wish to deal in this note, out of the question, air-quenching is applied to a certain number of nickel steels, and we can predict which steels will lend themselves to this air quenching. We know that nickel steels are either perlitic, or martensitic, or polyhedric. We likewise know that the martensite structure is the structure of ordinary well-quenched steels, and that the transition of one structure into the other depends upon the sum of (Ci + Ni) and upon the other elements as well; manganese and chromium in particular exert an influence of the same character as nickel.

The change from one structure to another is moreover not sudden.

There are steels which contain both perlite and martensite; it will be sufficient to apply air-cooling to render the structure all martensitic.

It is, therefore, steels bordering upon the martensite steels which will take air-quenching.

But these steels are inconvenient in one respect. A slight change in their chemical constitution will send them over to the class of martensite steels which are very difficult to work. Here are some examples of steels which will take air-quenching:

1. C = 0·75, Ni = 3 82, Cr = 1·28, Mn = 0·52, Si = 0·17.

Annealed: R = 97·0, E = 76·8, A = 12 per cent, Σ = 40, impact = 30.

Air-quenched at 850°: R = 135, E = 132, A = 10 per cent, Σ = 20, impact = 8. (Brittleness less after than before quenching.)

2. C = 252, Ni = 5·43, Cr = 0·52, Mn = 0·33, Si = 0·22.

Annealed: R = 76, E = 64·3, A = 18 per cent, Σ = 60·2, impact = 20.

Air-quenched at 850°: R = 123, E = 105·4, A = 10 per cent, Σ = 48·5, impact = 12.

Water-quenched at 850°: R = 143·5, E = 128, A = 8 per cent, Σ = 42·3, impact = 10.

3. C = 0·366, Ni = 4·76, Cr = 0·92, Mn = 0·41.

Annealed: R = 95 to 100, E = 80 to 85, A = 12 to 15 per cent, Σ = 55 to 60, impact = 12. (Figures given by manufacturer.)

$R = 143$, $E = 120$, $A = 7$ per cent, $\Sigma = 38{\cdot}7$, impact $= 6{\cdot}5$ (values we determined).

Quenched in air it should yield according to the manufacturer: $R = 159$, $E = 125$, $A = 8$ per cent, $\Sigma = 40{\cdot}1$, impact $= 8$.

This last-mentioned steel exemplifies — in so far at least as my own experience goes — what I said above concerning decidedly martensitic steels.

Those steels would evidently *a fortiori* lend themselves to water-quenching; indeed their mechanical properties would be enhanced by this treatment. But the very simple air-quenching will do quite well in many cases.

The third actual tendency noticeable in the manufacture of special steels concerns the augmentation in carbon percentage in the case of steels for rubbing surfaces.

Broadly speaking carbon is certainly the best agent which will impart mineralogical hardness. Chromium has the same effect, but it cannot equal carbon. For certain parts, where brittleness is less to be feared, the carbon percentage is increased as it seems to be correlated with wear by friction.

In exemplification I give the compositions of two steels which are made by the same French firm.

Type 1: $C = 0{\cdot}330$, $Ni = 2{\cdot}43$, $Cr = 0{\cdot}42$, $Mn = 0{\cdot}43$, $Si = 0{,}26$.

Type 2: $C = 0{\cdot}626$, $Ni = 2{\cdot}6$, $Cr = 0{\cdot}54$, $Mn = 0{\cdot}22$, $Si = 0{\cdot}32$.

Personally I am not an advocate of high carbon percentages, and in practice — leaving apart the silicon steels which may contain up to 0·600 per cent of carbon — the metals which answer best are those containing at the highest 0·400 per cent of carbon; in a good many instances it will indeed be advantageous to keep below this figure.

To sum up, the three years which have elapsed since the last Congress have only justified the conclusions at which we had arrived in the short note then presented: The industry of special steels for structural purposes turns more and more to the perlitic steels, and among these the nickel-chrome steels claim a position of increasing importance.

It cannot be said that new types of steels have been created since the Brussels Congress. Yet certain steels which were already made at that period, but were not widely applied, have taken a great commercial devepolment. These are the simple or complex vanadium steels, which have been gaining ground in America above all other countries, and the nickel-steels, with or without chromium, which border upon the martensite steels and take air-quenching.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

I3

THE HEAT TREATMENT OF SPRING STEEL.

By **Lawford H. Fry**, Paris.

The following is an account of a series of tests made at the Baldwin Locomotive Works in 1907, to determine the effect of certain heat treatments on the transverse elastic limit and on the modulus of elasticity of the steel commonly used in America for locomotive carrying springs.

The points under investigation were:

1. The effect of annealing.

2. The comparative effect of quenching in water and in oil.

3. The effect of re-heating the steel to various temperatures after complete cooling in water or in oil.

The steel experimented upon was Basic open Hearth Spring Steel, furnished by the Carnegie Steel Company, and its chemical composition was:

Carbon	1·01 %
Manganese	0·38 %
Phosphorus	0·032%
Sulphur	0·032%
Silicon	0·13 %

The test pieces used were one inch in diameter and 14 inches long, with a uniform circular cross-section. Ten test pieces were cut from the same bar of steel, stamped with numbers 11 to 20 and treated as indicated in Table I which also shows the effect of the treatment on the physical quality of the steel.

Method of Heating and Cooling the Test Pieces.

In the experiments, the temperature at which the specimens were quenched was not varied, as experience has shown that there is a definite temperature for any given steel, size of work and method of quenching, at which the steel should be quenched to obtain the best results. Steel can be hardened by heating it to and quenching it at any temperature equal to or higher than its "critical point", but the higher the temperature at which it is quenched, the coarser becomes the grain and the more brittle the steel. It is therefore desirable to quench the steel close to the critical point, but in practice it is found necessary to allow a certain margin above the theoretical hardening temperature. This margin above the critical point is affected by the sizes and shape of the work and the method of quenching. Having been once determined this proper quenching temperature should be always used, any variation in the final degree of hardness being produced by a change in the temperature at which the temper is drawn, or the heat conductivity of the quenching bath.

By means of a magnet the "critical point" or point of recalescence of the steel experimented upon was found to be 1360° F. Previous experience with the steel has shown that for annealing, the steel should be heated to 40° or 50° above the critical temperature, and that for hardening it should be brought to 50° or 100° above the critical temperature, the exact temperature being determined by the size of the work and the effectiveness of the cooling bath.

For the present investigation the following temperatures were decided upon, they having been indicated by previous experience to be the most desirable:

for annealing	1400° F
for quenching in oil	1450° F
for quenching in water	1425° F

All the operations were carried out at these temperatures, and the heats at which the temper was drawn and the mode of quenching were the only variables in the heat treatment.

The test pieces were heated in a lead bath specially constructed to secure control and uniformity of temperature. The lead was contained in a cast iron pot placed in a circular brick-lined

furnace. Six burners uniformly spaced, admitted a gas-blast at a tangent with the brick walls, so that the flame rotated around the lead bath without impinging upon it at any point. The temperature of the lead bath was registered by means of a Bristol electric pyrometer.

For annealing, the test pieces were plunged in the lead, the bath heated to 1400^0 and kept at that heat for two hours, and then allowed to cool off naturally with the furnace, the top of the pot being covered. The time of cooling was fourteen hours.

For hardening, the test pieces were brought to the temperature indicated above and then quenched: 1^{st} In oil at a temperature of 80^0 F. The oil used conformed to the Baldwin Locomotive Works specification for tempering oil, which requires a fire test of 600^0 F or over, and a specific gravity of not less than 25^0 B at 60^0 F; or 2^{nd} In pure running water at 60^0 F. The test pieces, while being quenched, were kept agitated until cooled to the temperature of the bath.

For drawing the temper up to 600^0 F, the test pieces were placed in an oil bath heated by gas, the temperature being registered by means of a mercury thermometer; for drawing the temper above 600^0 F the test pieces were placed in the lead bath, the temperature being registered by the Bristol pyrometer. After the temper was drawn to the desired temperature, the test pieces were taken out of the bath and left to cool naturally in the air.

Method of Testing.

All the specimens were tested transversally. They were placed on supports twelve inches apart and the loads applied in the middle. The arrangement of the forged steel base *B* and the tool

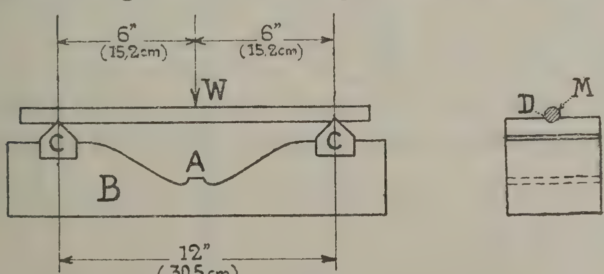


Fig. 1.
Test Piece and Support.

steel blocks C is shown in the sketch below. The bottom of the base was carefully planed and finished and the tool steel blocks C, supporting the specimens, had been scraped to exactly fit the base, so as to allow of no play or deformation when the loads were applied. The top of the tool steel blocks was rounded off at D, to the shape of the test pieces, so as to give a good bearing; but even so it was found that the blocks would cut into the test pieces one or two thousandths of an inch, and in order to remove as far as possible any error in the measurement of the deflections due to this cause, the specimens were subjected, before the test was begun, to the repeated application and release of a load which stressed them to about two-thirds of the elastic limit. This load was applied and released often enough to seat the test piece on the supports without giving it a permanent set, When the test piece was seated, the test proper was begun, and the height and deflections of the bars measured at their centres, with an inside micrometer, measuring to 0,00001 in., one point of which rested in a small center punch hole in the base, shown at A. The deflections were increased by steps of 0,0005 in. at a time and the loads measured for each increment of deflection. After having begun a test, the test piece was not released until the test was ended, as this was found to be the most accurate method; there is therefore no record of the permanent sets above the elastic limit.

Results obtained.

The results obtained are shown in Table I and also in the stress-strain diagram in Fig. 2. (See page 6.)

The elastic limit is that point where the ratio of deflection to stress ceases to be appreciably constant and the deflection begins to increase at a faster rate than the stress.

The fibre stresses, elastic limit and modulus of elasticity were calculated from the usual formulae for a simple beam, supported at both ends, and loaded at the middle as follows:

$$S = \frac{W l c}{4 I} \ldots (1) \qquad f = \frac{W l^3}{48 E I} \ldots (2) \qquad E = \frac{W l^3}{48 f I} \ldots (3)$$

and combining (2) and (3),

$$f = \frac{S l^2}{12 E c} \quad \text{and} \quad E = \frac{S l^2}{12 f c}$$

where,

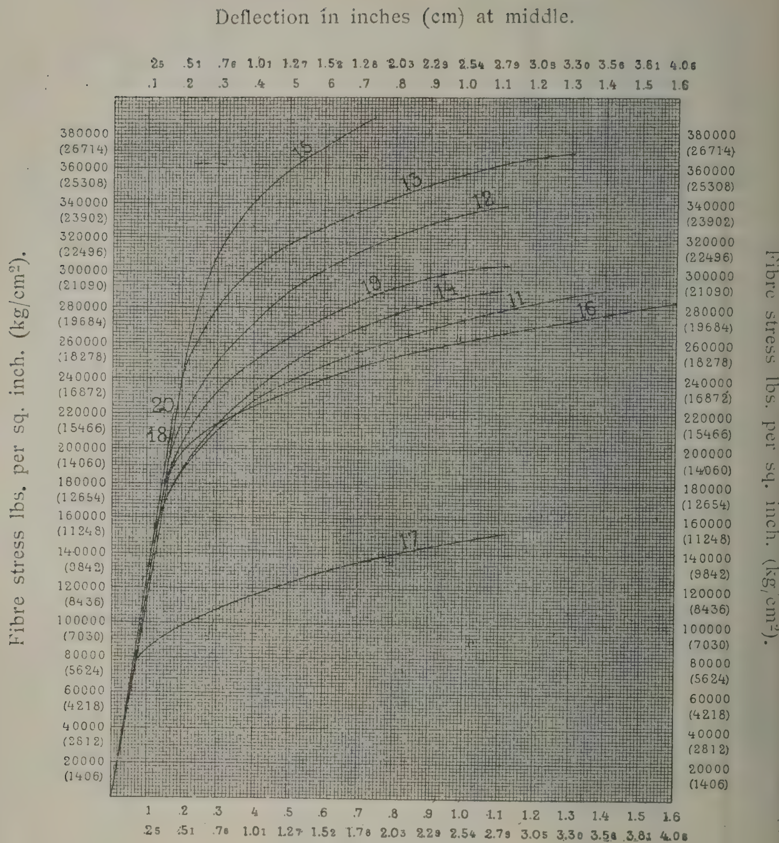
Table I.

The Heat Treatment of Spring Steel.
Results of Tests:

No of Tests	Heat Treatment	Elastic Limit	Modulus of Elasticity	Diam. of test piece	Moment of Inertia	Brkg. deflection inches
17	Annealed in lead at 1400° F	78.500	27,550.000	0·991	0·04730	Did not brk.
11	Hardened in oil at 1450, drawn to 560° F	137.500	28,700.000	1·000	0·04909	„
14	„ „ „ „ 1450, „ „ 500° F	160.400	27,150.000	1·000	0·04909	„
19	„ „ „ „ 1450, „ „ 400° F	177.600	29,080.000	0·991	0 04730	„
12	„ „ „ „ 1450, not drawn . . .	187.400	28,610.000	0·993	0·04772	„
16	„ „ water „ 1425, drawn to 1050° F	180.700	28,070.000	0·997	0·04850	„
13	„ „ „ „ 1425, „ „ 900° F	233.900	28,860.000	0·998	0·04870	„
15	„ „ „ „ 1425, „ „ 750° F	240.800	29,220.000	0·994	0·04790	0·744
20	„ „ „ „ 1425, „ „ 600° F	219.800	30,420.000	0·991	0·04730	0·175
18	„ „ „ „ 1425, not drawn . . .	212.000	29,960.000	0·991	0·04730	0·175

Test pieces 17, 11, 14, 19, 12, 16, 13, did not break under a deflection at the middle of 1·1 inch.

Test pieces with uniform round cross-section placed on supports 12″ apart, load applied in middle. Chemical Analysis of Steel used: Carbon 1·01, Phosphorus 0.032, Manganese 0·38, Sulphur 0·032, Silicon 0·13.



Deflection in inches (cm) at middle.

Fig. 2.

S = maximum fibre stress in lbs. per sq. in.

W = load in middle in lbs.

l = span = 12 in.

I = moment of inertia of cross-section $= \dfrac{\pi d^4}{64}$ for a round section

f = deflection in the middle in inches

E = modulus of elasticity

c = distance of neutral axis to outermost fibres $= \dfrac{d}{2}$

d = diameter of test pieces in inches.

Discussion of the Results.

Annealing. The steel used in the tests, when thoroughly annealed in the manner above described, had an elastic limit of 78.500 lbs. This as shown below, is equal to about one-half the elastic limit generally obtained with this steel when given a "spring temper", and is equal to about one-third the elastic limit of the same steel when quenched in water and drawn to 750° F.

Oil Hardening. The highest elastic limit obtainable with the steel used, when quenched at 1450° F in oil, was 187.400 lbs. per square inch and this was obtained when the temper was not drawn after quenching. The higher the temperature to which the temper was drawn, the lower the elastic limit fell. Drawing to 400° F gave 177.600 lbs., drawing to 500° F gave 160.400 lbs., and drawing to 560° F 137.500 lbs. per sq. in. elastic limit. As will be seen from the diagram, none of the oil treated specimens broke under a 1·1 in. deflection. The usual "spring temper" given in shop practice would be: Quenching from about 1450° F in oil and drawing the temper to between 400° and 575° F. It will be seen that this practice would give an elastic limit varying from about 130.000 lbs. to about 175.000 lbs. per sq. in., or an average of about 150.000 lbs. per sq. in.

Water Hardening. When the steel was quenched at 1425° F in water and the temper not drawn after quenching, the steel was brittle and broke at 212.000 lbs. modulus of rupture, the elastic limit being the same as the modulus of rupture and the deflection of the breaking point being 0·171 in.

(The term "modulus of rupture" has a conventional meaning. It expresses in lbs. per square inch the apparent maximum fibre stress, tension or compression, of a member transversally loaded, as it is just on the point of breaking; the stress being calculated by the common beam theory, with its three important assumptions, which are known to be inaccurate above the elastic limit.)

Drawing the temper to 500° F gave an elastic limit of 219.800 lbs. with the elastic limit still equal to the modulus of rupture, or in other words, the ratio of stress to strain was constant up to the breaking point. The deflection at the breaking point was 0·175 in. Drawing the temper to 750° F gave the highest elastic limit: 240.800 lbs. per sq. in. and the modulus of rupture was then higher than the elastic limit, viz: 389.000 lbs. per sq. in.

The deflection at the breaking point was 0·744 in. If the temper was drawn to 900^0 F the elastic limit fell slightly, being 233.900 lbs. and the specimen did not break under a 1·1 in. deflection. When the temper was drawn to 1050^0 F the elastic limit dropped to 180.700 lbs. and the test piece did not break under a 1·1 in. deflection.

The Modulus of Elasticity.

The results of the tests show that the modulus of elasticity is practically constant and apparently independent of the heat treatment given. The modulus of elasticity is difficult to accurately determine, on account of the precision required in measuring the deflections and loads, which vary by very small amounts. It is to be noted that any error in the measurements is likely to make the value of the modulus smaller than it really should be. The modulus of elasticity is the ratio of the stress to the strain, or in this case the modulus of elasticity $= E$, varies as $\frac{\text{stress}}{\text{deflection}}$. Now, all measurements of the deflections have a tendency to be too large and consequently the values found for E have a tendency to be too small, because the blocks and base on which the specimens rest are compressed to a certain amount by the loads on the test pieces, and if not perfectly fitted, the blocks take a certain set which, together with the compression of the support, is measured with the true deflection of the test pieces and added to the true deflections in all the computations. Also, the softer the test pieces, the more difficult it is to prevent the supports from denting it under load. The values obtained for the modulus of elasticity varied from 27,150.000 to 30,420.000. It would seem that the higher values are more probably correct and that the true modulus of elasticity of the steel apparently lies between 29,000.000 and 30,000.000 and is probably unaffected by the heat treatment.

Conclusions.

Steel of $1^0/_0$ of carbon, when quenched in cold water from above its "critical point", is usually too hard and too brittle to be used for the making of springs or tools. The theory of the hardening of steel tells us that there are two ways of modifying this hardness and brittleness of the steel. They are 1st. Allowing some of the carbon

fixed in the "hardening" form by quenching, to change back to the "annealing" form, by re-heating the steel above 400° F. The higher this re-heating or "drawing of the temper" is carried, the softer the steel becomes. 2nd. Using a quenching bath having a lesser heat conductivity. The slower the steel is cooled from above the "critical point" to about 400° F, the more carbon is allowed to change to the "annealing" form and the less the steel hardens. By the second method, steel can be obtained of different degrees of hardness without "drawing the temper" after hardening the steel. These two methods of regulating the hardness of steel in hardening can also be used jointly.

These points are illustrated in the tests. The higher the temper is drawn after hardening, the lower the elastic limit falls; also a lower elastic limit is obtained with the test pieces quenched in the bath having the lesser heat conductivity, viz, oil. The tests show that the elastic limit of 1% carbon steel can be made to vary from 78.500 lbs. per sq. in. to 240.800 lbs. per sq. in., by changes in the heat treatment, and that very small changes in the "drawing of the temper" are sufficient to affect the elastic limit of the steel. This proves once more that the heat treatment of steel is a delicate and accurate operation and that to obtain good and uniform results, it is necessary to have means of heating the steel uniformly to the proper temperature and cooling it at the desired rate in a cooling medium, the temperature and heat conductivity of which can be kept reasonably constant.

The tests described above were carried out by Mr. François de St-Phalle.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

IV1

THE ENDURANCE OF STEELS TO REPEATED ALTERNATE STRESSES.

By **James E. Howard**, Watertown, Mass., U. S. A.

The results of tests on the endurance of steels to repeated alternate stresses have been available, as well known, for a long term of years, many experimenters having in turn taken up this line of inquiry since its early inauguration by the eminent Woehler of distinguished memory. Notwithstanding the extent of the information which has been developed on the general subject still the stages through which rupture is approached and ultimately effected is yet involved in obscurity.

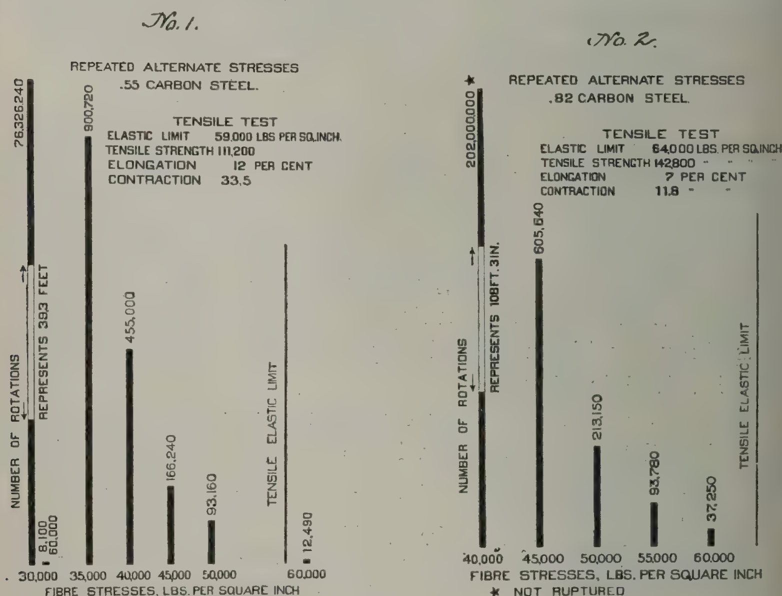
In view of the prevailing conditions and with the permission of the Association the subject will be taken up somewhat discursively after the presentation of a few results which have been obtained in the Laboratory at Watertown, Mass., U. S. A.

The tabulated results and diagrams refer to a series of tests conducted on six grades of Open Hearth steel, in which the carbon content ranged from 0,17 C. to 1,09 C. The material experimented upon was in the condition of hot rolled bars, finished as an ordinary commercial product.

The tests were made with cylindrical shafts the dimensions of which were one inch diameter and 33 inches long between end supports. The shafts were loaded transversely at the middle of their lengths by means of a double bearing the two parts of which were 4 inches apart, this kind of bearing being used for the purpose of uniformly straining a short portion of the length of the test piece. The shafts were rotated at a speed of 500 rotations per minute.

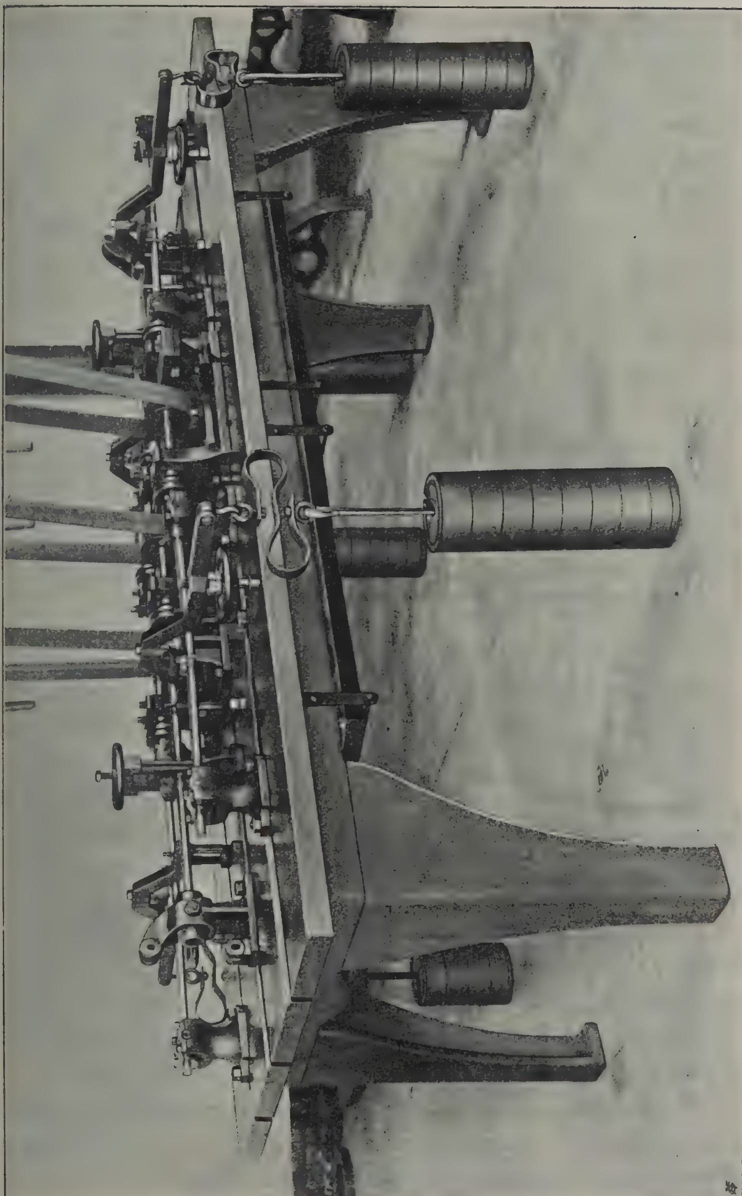
The accompanying photograph shows the repeated stress machine on which these tests were made.

On the diagrams which follow are indicated the number of repeated alternate stresses, of different magnitudes, which caused rupture of the several experimental shafts. The lower fibre stress employed, 30,000 lbs. per sq. in., on a shaft of 0,55 C. did not result in the rupture of the steel. After enduring 76,326,240 repetitions the load was increased to 60,000 lbs. per sq. in., under which higher stress rupture occurred after 8,100 additional repetitions of the load.



Diagrams Nos 1 and 2.

The relative endurance of each of two grades of steel when subjected to different stresses will be seen upon inspection of the above diagrams. As the stresses are increased in magnitude and approach in value the tensile elastic limit of the steel there is shown a rapid decrease in the endurance of the material. The limiting stress for indefinite endurance, if remaining intact after several hundred million repetitions may be so designated, is very much below the tensile elastic limit. (The distances men-



tioned in diagrams Nos 1 and 2 representing 39·3 feet and 108 ft 3 inches respectively refer to the diagrams before their reduction in size (2,5 : 1) for printing).

On diagram No. 3, curves are plotted representing the number of alternate stresses of different magnitudes which were necessary to cause rupture in each of the six grades of steel comprised in this series of tests. A noteworthy feature of the tests is the superior endurance displayed by the two grades of steel, those of 0,73 C. and 0,82 C. respectively, which had their carbon content in the vicinity of the saturation point.

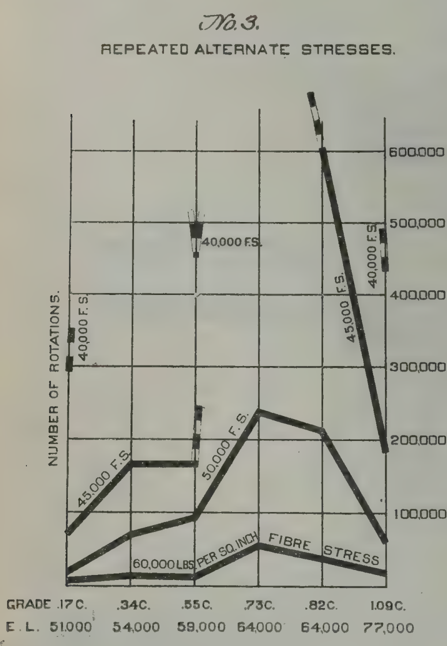


Diagram No. 3.

Passing now from the presentation of these few results, some remarks will be made on the behavior of steel, under different conditions of test, thought to be relevant to the general subject.

A conspicuous feature in the tests of steels by repeated alternate stresses is the rupturing of the metal by loads well within the elastic limit and the accomplishment of this result, in all grades of metal, without the display of appreciable permanent elongation or contraction of area. It indeed becomes an open question what value attaches to the ability of the steel to elongate or contract under conditions of loading in which there is practically no development of either feature.

This leads to a consideration of what properties contribute to the endurance of steels under the action of repeated stresses. While it is true that applied loads below the elastic limit ultimately effect rupture, there is reason for believing that the actual stresses which cause the separation of adjacent parts of the steel must

locally attain in magnitude the value of the tensile strength of the metal. Causes which militate against the uniform straining of the metal within itself necessary contribute toward the attainment of local stresses above the mean value.

The introduction of internal strains may bring about results of this kind and account for wide variations in the intensity of stresses in different parts of the steel. To what extent such variations may be due to a temporary lowering of the modulus of elasticity by reason of local overstraining of the metal is conjectural, but some variation might at times be due to this cause. Changes in density of a permanent character are known to occur as the result of the application of stresses above the elastic limit when such loads cause permanent changes in shape.

Provided changes in density and internal strains are cumulative in their effects then there would be reason for expecting that the strains due to the applied stresses of the test would be augmented by those from within and the real maximum stresses attain limits much above the nominal ones and approach the tensile strength of the metal in certain cases.

It is not considered essential that the phenomenon of ductility should always accompany stresses in going from the elastic limit to the tensile strength limit. Form favors the display of elongation and conditions which are favorable for such elongation in an ordinary tensile specimen may be absent when internal strains assist in causing rupture.

The usual effect of cold work, such as wire drawing for example, is to raise the tensile strength, and other kinds of cold treatment have a similar effect in raising rather than lowering the ultimate strength of the metal. So many illustrations will present themselves in which the tensile strength is raised by mechanical treatment that the effect of alternate stresses in apparently lowering it seems paradoxical in comparison.

It has been found that the number of loadings necessary to cause rupture is very much increased when the experimental shafts are tested at a blue heat, that is at temperatures ranging from 400 to 600 degrees F. It will be recalled that the tensile strengths of steels are higher in this zone of temperature than at ordinary temperatures.

This evidence favors the thought that rupture is eventually reached through the cumulative effect of internal strains aiding the applied loads, and that an increase in tensile strength, other properties remaining less affected, tends to prolong the endurance of the metal. Other explanations will present themselves but this seems a consistent one.

If the external metal of the experimental shafts, which from its position is exposed to the higher stresses of the test, is actually stressed to its normal tensile limit by reason of the cumulative effect of internal strains augmenting the applied forces, at the time of or immediately prior to rupture, then it would seem there should be no loss in tensile strength of the metal up to that period of the test and furthermore there might even be a slight gain in tensile strength from the cold working of the steel.

The examination was made of some annular specimens in which the metal at the neutral axis and beyond was removed, leaving only a thin external shell comprising that part of the shaft which had been exposed to the higher stresses of the test, and in a few instances it was thought that a higher tensile strength was displayed than normal to the steel. Slight as was this evidence yet it seemed consistent with the theory of rupture above advanced.

On the other hand experience has not always supported this theory, as the following remarks will show.

Provided the cumulative effect of internal strains tends to promote rupture, as supposed, then annealing at suitable temperatures should prolong the endurance of the steel since proper annealing eliminates such strains. In this way the endurance should admit of being extended perhaps indefinitely if the treatment was fully effective.

Efforts in this direction, however, have not met with success. The limit of endurance of shafts occasionally annealed was not sensibly increased. While the experimental results have not furnished the encouragement that was expected, still it is not thought that the tests were decisive. The question is a very important one whether the progress of rupture may be arrested and the metal restored to its primitive state.

The effects of overstraining are very persistent and have been found to remain in iron after the lapse of a period of 22 years, but the dislodgement may be immediately accomplished by exposure

to annealing temperatures. Inasmuch as the restoration of certain features in the tensile properties may be effected by annealing, it has led to the hope that beneficial results from annealing may yet be found to follow in respect to the endurance of metals under repeated stresses.

In submitting these remarks it has been desired to direct attention to causes which may assist in explaining the phenomena of rupture by repeated stresses, and as worthy of consideration the thought has been advanced that accumulated internal strains augment the applied forces. It is important that such an understanding of the subject be arrived at, if possible, as may result in the recognition of the controlling factors which give to steels the ability to endure long continued stresses. It is hoped that the members of the Association may kindly add the thoughts and impressions which they have received to the end that the underlying and fundamental features involved may eventually be understood.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

VTH CONGRESS, COPENHAGEN 1909.

X 2

UNIFORM TESTS OF HYDRAULIC CEMENTS BY MEANS OF PRISMS.-STANDARD SAND.

Report of the Chairman of Committee 42:

Prof. **F. Schüle,** Zurich.

Translated from the German by A. R. Liddell.

1. The ascertainment of the strength of the hydraulic cements for the determination of their comparative qualities is in general achieved by means of the subjection to tensile and compression tests of test-samples consisting of mortar of the consistency of 1 part cement to 3 parts standard sand together with a varying quantity of mixing-water, either pressed together by hand or rammed by machine power, according to the country in question.

After the Congress held in Buda-Pest in 1901 two referees were nominated for the study of the question of standard sand, and at the Brussels Congress the author of this report had an opportunity of discussing the properties of sands of the kinds that come in question for the testing of hydraulic cements in a fairly thorough manner.

The conclusion of this study consisted in the giving of the preference to those kinds of sand which pass through the 64 mesh sieve and are held back by one of 120 or 144 meshes, over the mixed-grain kinds which are retained by 4 sieves with round holes of 2, 1·5, 1 and 0·5 mm in diameter in the manner that the materials remaining on the three last sieves, or that remaining on the second and on the last ones, are mixed together in equal parts by weight.

As a further result of the study, it appeared that the question of a standard sand could not bring a solution for the uniform testing of the hydraulic cements, and the proposal which has become the object of the labours of Commission No. 42, was accordingly made.

The Committee was constituted in the spring of 1907 in the following manner.

Chairman of the Committee: Prof. F. Schüle, Zürich.

Members: Laboratoire des Ponts et Chaussées, Boulogne s/M. (R. Feret); Laboratoire des Ponts et Chaussées, Paris (A. Mesnager, Mercier); Laboratoire du Conservatoire des Arts et Métiers, Paris (Leduc); Kgl. Material-Prüfungsamt, Gr.-Lichterfelde (Prof. Dr. Ing. A. Martens, Prof. M Gary); Laboratorium des Vereines deutscher Portland-Zementfabrikanten, Karlshorst bei Berlin (Dr. Framm); Eidgenössische Material-Prüfungsanstalt, Zürich (Prof. Schüle); Mech. Laboratory of the Imp. Institute for Road-building, St. Petersburg (Prof. Dr. Ing. N. Belelubsky, Prof. Bogdansky); Mechanisch-technisches Laboratorium der technischen Hochschule, Wien (Prof. B. Kirsch); Danish State Testing Laboratory in Copenhagen (Mayntz Petersen); Ecole d'applications pour les Ingénieurs, Bologna (Prof. S. Canevazzi); Laboratoire de l'arsenal de l'Etat Belge, Malines (E. Camerman); Material-Prüfungsanstalt von Bienfait & Koning, Amsterdam (L. Bienfait); Materials Testing Laboratory United States Geological Survey (Rich. L. Humphrey), Philadelphia Penna.

Most of the testing laboratories declared their willingness to undertake investigations, the results of which are put together in the following report and give good hope that a simple, exact, and uniform method for the testing of the strength of hydraulic cements will be attained in the near future.

2. The operations were begun by the issue, by the Chairman of the Committee of the following circular dated May 16th., 1907.

"The wish to attain comparable results from the strength tests made on hydraulic cements has already, in the Bauschinger Conferences and in the Congresses of our Association, led to the institution of various attempts towards the attainment of uniformity in connection with: the manner of producing the test samples, machines for the testing, sand for the mixing of the mortar, and the quantity of water suitable for the latter process. Complete

unanimity on these points has not yet been attained, and the task of finding a uniform standard sand, in regard to which various communications were made to the Congress in Brussels, confirmed in 1906 what had been already made clear in connection with the Bauschinger conference in Vienna in 1892, that the solution of the sand question alone would not be sufficient, but stood in close connection with the larger one of the attainment of uniformity in the whole method of testing.

The Process applied in the strength-tests of hydraulic cements has in each country been the outcome of long-continued investigations, and it is not likely that a considerable revolution in favour of the approval by our Association of a method used by one particular country will ever become possible. Notwithstanding this, however, there are numerous cases, in which it would be of advantage to obtain strength-values of the kind, which could be directly compared one with another, in whatever testing-laboratory or country such tests might be made.

In view of this, the undersigned made the proposal at the Brussels Congress, that a general agreement be come to, that for purposes of comparison the strength of hydraulic cements be determined by means of $4 \times 4 \times 16$ cm prisms of mortar of 1 : 3, in the manner in which such have for years been applied by Mr. Féret in the Laboratoire des ponts et chaussées, in Boulogne-sur-mer, the sand there in used being a quartz-sand obtained by the aid of sieves of 64 and 144 meshes to the sq. cm. respectively; the prisms here to be first submitted to a bending test, after which the halves of each broken test-sample were to undergo the compression test.

In view of its uniformity and of the control exercised in its production, the German standard-sand of Freienwalde was recommended as the most suitable sand material.

The proposal that investigations be made on these lines obtained the support of the Congress, and the Council nominated a special committee for the solution of this question. A number of testing-laboratories have expressed their readinesss to co-operate in these experiments, and I beg herewith to express my thanks to them.

It would be of advantage to hear the various views as to the best manner of pursuing the investigations for the solution

of this question. In view of this, then, I beg to submit a draft programme of the work to be undertaken, with an invitation to the members of the Committee to give expression to their views and make communication of any alterations to these proposals which they may deem desirable.

In every testing laboratory, the introduction of a new process entails getting accustomed to the various details which characterize it, and the ascertainment of the relations existing between the results of the tests hitherto made by the official method in use in such establishment on the one hand and those of the proposed method on the other.

After the accomplishment of this introductory work it will be possible, simultaneously to carry on several series of tests with one or two cements, which would be sent to all the testing laboratories that would interest themselves in the question.

The prism-testing process has become familiar to us through the publications of Mr. Feret. In connection with the application of this process in the Federal Testing Laboratory in Zurich, special moulds, which can easily be taken asunder and are held together by a single screw, have for several years been in use for six samples each, while, for the bending test, the Michaelis apparatus for tensile tests is provided with a special fitting in the shape of a stirrup. The accompanying notice gives the details of the process and a suitable method for the determination of the quantity of the water.

The investigations which I beg to propose are the following: —

a. Preliminary Experiments. — Parallel experimental tests lasting for 7 and 28 days respectively on a few cements to be made on the prism method and in the manner usual in each laboratory, with the standard sand of the respective country and with German standard sand from Freienwalde.

b. Comparative Experimental Tests. — The testing of two Portland cements which are to be sent from a central point to all testing establishments that agree to take part in these tests, by the method usually employed in each particular establishment and by the process with prisms and German standard sand. The tests would take place after periods of 7 and 28 days.

The preliminary experiments can be carried out within the next few months; when the process with prisms shall, by means

of these, have become better known in the various testing laboratories, the two series of Portland cements to be tested can be despatched to the different laboratories, if possible in the course of the month of November, 1907.

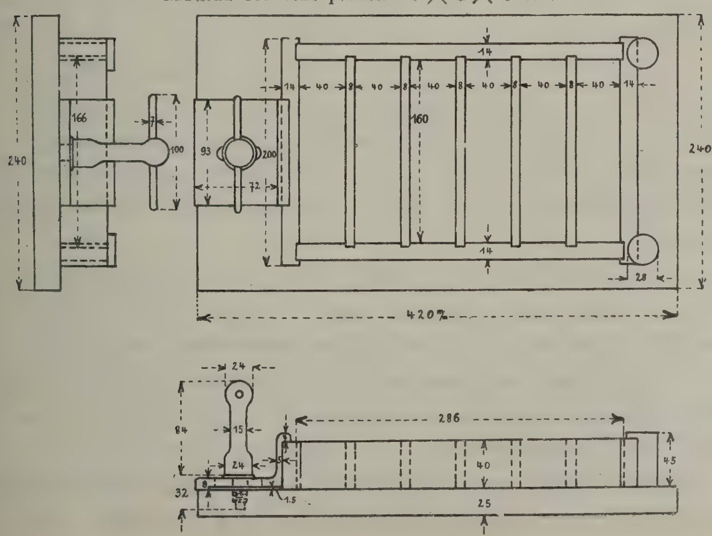
Results of these investigations could be collected up till the beginning of the Spring, 1908, and communicated to those interested, so that the investigations might, if necessary, be supplemented during the course of the year.

I shall feel obliged if the Members of the Commission will give expression to their views on the programme submitted, and will, if possible, send in their answers before July 15th., 1907.

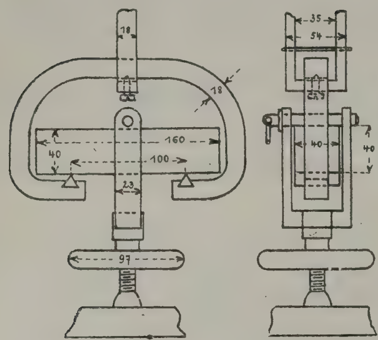
3. This circular was accompanied by the following description of the method in use in the Federal Testing Laboratory in Zurich for the production and testing of standard mortar prisms of 1 to 3 in plastic consistency.

I. Apparatus. — In accordance with the accompanying drawing, the samples are produced in iron moulds each of which is made in 6 parts and, on the release of a screw at one end, can easily be taken asunder. Each division of the mould has an area of 4×16 cm and a height of 4 cm. To prevent the adherence of the mortar to the iron, the surfaces are rubbed with a greasy cloth before the mould is put together.

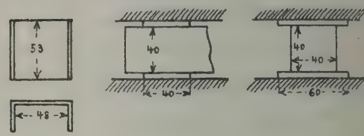
Moulds for test pieces $16 \times 4 \times 4$ cm.



Arrangement for bending tests.



Plates and angle iron for compression tests



The bending is tested by the Michaelis apparatus, which, in place of the grips usually employed for octagonal block samples, is provided above with a stirrup with two knife-edges 10 cm apart and below with a small frame with a removable cross-bar as in the accompanying drawing. The prisms are introduced into the stirrup in the horizontal position and between the cheeks of the frame. The iron cross-bar of the lower frame is then inserted and brought into the middle of the field of support.

Half of the prisms are laid on a press between steel plates 4 cm in breadth. To insure that the plates lie exactly one above the other, an angle iron is made use of, as shown in the drawing.

II. Mixing of the Mortar. — For the simultaneous production of 6 prisms 2·700 kgs of standard sand and 0·900 kgs of cement are simultaneously mixed dry in a shallow vessel, after which water is gradually poured in and the mass is then vigorously worked through by hand with the trowel for from 3 to 5 minutes.

For the plastic consistency, the mortar requires from $1\frac{1}{2}$ to 2 per cent more water, than for the usual normal consistency for ramming. According to experiments made, the quantity of water required can also be determined by the number of blows (35 to 45) required to cause water to trickle from a cube, rammed in the apparatus.

III. Production of the Prisms. — Each division of the 6-part mould is at once half filled, so that the water does not

flow from one compartment into the others during the process of ramming.

The easy and rapid ramming operation is effected by hand with a pestle or rammer 1 kg in weight and 3×3 cm in section, the ramming effect being produced merely by its own weight after being raised from 0,5 to 1 cm.

After the surface of the mortar has been scraped off, there comes the second filling of all the compartments, which after ramming, must be sufficient in quantity to completely fill the mould so that some material has to be removed; the water then collects on the surface. After this the mould is shaken a few times on the moulding table and its surface smoothly scraped off with a straight-edge.

IV. Method of Keeping the Samples. — The samples remain in their places till the material sets, that is to say until they can be easily removed from the mould; in the case of Portland cement this condition is generally reached in about 24 hours; the prisms are kept on a brass plate in the moist closet for about 8 to 12 hours more, and are then immersed in water until just before the test.

V. Conduct of the Test. — The bending test is conducted in such a manner that the part of the prism which was uppermost in the moulding process is also uppermost in the stirrup. The weight of the shot-tray multiplied by 11,7 gives the bending-strength, which is equal to twice the tensile strength.

The compression-test on each half prism is made by the canting over of the prism through an angle of 90^0, so that the pressure is applied in a direction lateral to the ramming, that is to say the two sides adapt themselves better for the distribution of the pressure on account of their smooth plane surfaces. The mean of the results with the two halves of a prism is set down as the compression strength.

Of the six values given by a series, the arithmetical mean of the four best ones is looked on as the authoritative result.

4. The procedure thus initiated obtained the approval of most of the testing establishments, but on the other hand several important observations were submitted by Mr. Féret, which in the main bore reference to the following points:

a) The sand of uniform size of grain limited by the 64 and 144 meshes is not very suitable for the production of plastic mortars; for, according to Mr. Féret, the water mixed with cement will easily flow between the grains, so that the mortar does not become homogeneous. The mixed-grain sand would not be subject to the same disadvantages, and a mixture would not be incompatible with the use of the Freienwalde Sand, which in its crude condition contains about 50 per cent (by weight) of grains limited in size by perforated plates with holes of 2, 1,5, 1, and 0,5 mm respectively.

b) One of the advantages of the plastic mortar consists in the independance of special machinery, which it gives; on this account it is illogical to determine the quantity of the mixing-water by means of the ramming apparatus.

The definition of a uniform consistency is one of the chief difficulties attending the use of such mortar, and it would be desirable, that the determination of the quantity of water that is necessary for the attainment in every case of mortars of the same consistency with every cement should be referred to the Committee as one of their most important tasks.

c) It would be desirable that the degree of rammability of the mortar in the moulds should be determined. Every laboratory was invited to make trial of the proposed method, to improve it, and to propose alternatives.

d) Mr. Féret takes exception to the bending test with load concentrated in the middle, on the ground that the section at this point has to take compression and shearing strains in addition to the bending strains proper, and he declares himself in favour of the employment of symmetrical loads, which, in the field in which the fracture occurs, give a constant bending moment without the cooperation of the shearing force. The arrangement advocated by Mr. Féret is to be found in his book "Etude expérimentale du ciment armé", and was explained at the Brussels Congress.

e) In connection with the bending test, Mr. Féret would give the preference to the application of the power against the lateral surfaces of the prism, since during the moulding process the uncovered surface is not so regular as the three others, and moreover has not always the same composition as the rest of the piece on account of the action of the outer air during setting.

f) It would be illusory to attempt to discover a definite proportion between the bending strengths obtained by the new method and with plastic mortar and the tensile strengths with rammed mortar, which may have been determined by the methods at present in use in the various laboratories. Such experiments have always shown that no proportionality exists, which is an almost unavoidable consequence of the difference between the two methods.

5. These observations, which are communicated to the Members of the Committee, have contributed in an effective manner to the more exact determination of the programme of the operations. The preliminary tests, have, notwithstanding this, been carried out in the sense in the first circular and in accordance with the method therein described, for the following reasons:

A method for the testing of hydraulic cements is in various respects arbitrary. This is the case with all tests which give comparative and not absolute results.

Committee No 42 wishes to try to give uniformity to the method for the comparison of the strength values determined in different countries and different laboratories. The method is not intended to replace older ones, that are exactly marked out, but are different in the various countries. This uniform method is to be specially distinguished by its simplicity.

For this reason the particular sand was proposed as a standard, which is obtained between sieves of 64 and 144 meshes — in particular, that of Freienwalde. Between this sand and that which includes 3 sizes of grain (sieve with holes of 2, 1,5, 1, and 0,5) in equal parts by weight, there is a difference of 6 per cent in the unfilled spaces (interstices). It is scarcely probable that this difference is sufficiently considerable to characterize the one mortar of 1 to 3 as homogeneous and the others as non-homogeneous. The difficulty of obtaining the fine sand (0·5 to 1 mm,) in a homogeneous state, and of always mixing the three sizes of grain in the same given proportion for test-samples that are to be exactly alike, is greater than that which arises from the larger hollow spaces referred to above.

The investigations which have been made in countries other than France with mixed-grain sands did not show favourable results for such sands; for this reason it seemed advisable that

the sizes of sand-grain which are in pretty general use should be adhered to.

The determination of the proportion of water which is suitable for the plastic mortar is one of the greatest difficulties. Most of the testing laboratoires are in possession of ramming apparatus for the mortar-tests (either on the Böhme or on the Klebe-Tetmajer system). It is possible, by the aid of this apparatus, to ascertain the mechanical work applied in ramming, and in this way to determine the proportion of water necessary for the attainment of a given consistency of the mortar. After a few experimental tests in this direction, it will be possible to fix a proportion between the quantity of water used for plastic mortar of 1 to 3 and the quantity which corresponds with the standard consistency of pure cements.

The ramming test with the machine is given as a fairly practical and provisional means of determining the suitable quantity of water.

In the case of bending tests which give a constant moment in the central field, the shearing force is, indeed, avoided, but, at the points in which the forces act, the bending moment and the shearing force are always present. If the shearing force exercise an unfavourable influence on the strength, fracture will occur under the points of application of the load, and not between these points. Should fracture occur between these points, this means that the shearing force does not act in a disadvantageous manner, or that there is a weak place between the points of application of the load on the test sample, so that the result will be more likely to be an abnormal one. The arrangement which is applied in the Federal Testing Laboratory in Zurich has produced good results. A comparison between the method with constant moment and that with concentrated load will show which of these gives the more consistent results; the better one should then be applied. The interesting results contained in Mr. Féret's work on reinforced cement are not at variance with the foregoing remarks, since the experiments with constant bending moment and those with concentrated load showed the same regularity (page 592), the figures obtained by the first-named method, however, being smaller by 14 per cent than those by the second one; this cannot be regarded as an advantage.

It would appear to be necessary, that definite information be as soon as possible obtained as to the proportion existing between the strengths attaching to the new methods and those due to the methods hitherto in use; for it is hardly to be expected that any uniform method can find acceptation side by side with the existing ones, so long as the influence that the new results may be expected to exercise on the classification of the hydraulic cements, remains unknown.

6. The preliminary experimental tests set forth in my circular of May 16 th., 1907, have been carried out in several testing laboratories and up to January, 1908, I received the results from the Laboratories of Karlshorst (Dr. Framm), Bologna (Professor Canevazzi), Amsterdam (Eng. Bienfait), Vienna (Prof. Kirsch), and Zurich.

The tests were made with Portland cement in accordance with the directions contained in the "notice for the production of prisms" enclosed in my circular, and at the same time also in accordance with the methods of testing usually employed in the respective laboratories.

Have the first experiments given a favourable result?

Is it necessary to improve or modify the proposed prism-method?

The results obtained enable a preliminary answer to be given to these questions:

The absolute amount of the strength is not taken particularly into account, and is only given in connection with the results of the 7-day and 28 day tests of the rammed moist mortar, in order to compare the relative strengths that are obtained when the strength of earth-moist mortar is taken as the unit.

The following table contains the particulars of the results already received. (See table page 12.)

It is to be observed that bending and tensile tests do not necessarily give the same proportion between the strengths as compression tests, since, in the first case, half the bending strength is compared with the tensile strength, while, in the second, two compression strengths are compared.

The latter proportion is, in general, somewhat less than the former one. The figures of comparison vary also, according to the quality of the cement submitted to test and according to the length of

Number	Laboratory	Number of the Portland Cement	Sand	Mixing Water: Earth-Moist Mortar %	Mixing Water: Plastic Mortar %	Proportion borne by Plastic Mortar to Earth-Moist Mortar: Tensile Strength 7 days	Tensile Strength 28 days	Compressive Strength 7 days	Compressive Strength 28 days	Resistances of the Earth-Moist Mortar after 28 days: Tensile Strain	Compressive Strain
1	**Karlshorst** (German Cementmakers)	I	German Standard Sand	$8^1/_2$	$10^1/_2$	0·56	0·75	0·58	0·70	17·1	151
		II		$8^3/_4$	$10^3/_4$	0·67	0·72	0·62	0·72	26·4	336
		III		$8^3/_4$	$10^3/_4$	0·67	0·72	0·63	0·71	25·2	246
		IV		$8^1/_2$	$10^1/_2$	0·51	0·55	0·57	0·50	21·0	216
		V		$8^1/_2$	$10^1/_2$	0·65	0·70	0·70	0·72	23·4	283
2	**Amsterdam** (Koning & Bienfait)	A	German Standard Sand	8	$9^1/_2$	0·69	0·73	0·70	0·81	28·4	285
		B		8·1	8·9	0·78	0·72	0·67	0·66	18·6	202
		C		8·1	9·6	0·91	0·85	0·72	0·64	13·2	174
3	**Bologna** (School for Engineers)	1	German Standard Sand	not stated		0·61	0·57	0·50	0·41	31·6	343
						0·29	0·63	0·21	0·43	30·0	330
		2				0·53	0·47	0·33	0·29	25·4	265
						0·43	0·37	0·29	0·23	27·0	271
		3				0·63	0·57	0·34	0·40	29·0	286
						0·51	0·52	0·30	0·37	30·3	288
		4				0·72	0·74	0·32	0·45	32·3	424
						0·55	0·67	0·32	0·37	33·3	389
		5				0·59	0·74	0·39	0·39	26·4	298
						0·61	0·70	0·32	0·32	27·6	309
		1	Sand from Reno, Grains < 1,5, > 1 mm			0·49	0·44	0·46	0·42	37·8	314
						0·50	0·53	0·42	0·48	33·1	261
		2				0·35	0·40	0·32	0·33	29·5	251
						0·27	0·37	0·29	0·30	27·2	240
		3				0·59	0·66	0·34	0·56	31·3	289
						0·39	0·47	0·26	0·42	31·9	254
		4				0·51	0·69	0·40	0·49	36·1	338
						0·53	0·61	0·39	0·47	34·0	341
		5				0·51	0·63	0·41	0·51	32·1	284
						0·50	0·72	0·49	0·59	28·7	248
4	**Zurich** (Polytechnic School)	J	Swiss Standard Sand	$9^3/_4$	$11^1/_2$	0·86	0·85	0·66	0·83	39·4	522
		D		$9^1/_2$	$11^1/_4$	0·85	1·00	0·64	0·83	23·9	297
		R		$9^3/_4$	$11^1/_2$	0·74	0·78	0·68	0·76	36·1	357
		J	German Standard Sand	8	$9^3/_4$	1·11	1·18	0·81	1·00	29·8	530
		D		8	$9^3/_4$	0·94	0·04	0·85	1·04	21·6	295
		R		$8^1/_4$	$10^1/_2$	1·11	1·10	0·96	1·03	25·6	320

time during which the test-samples have been kept. The comparative figures from the experimental tests given are the following:

Running No.	Laboratory	Standard Sand	Tensile strength after 7 days	Tensile strength after 28 days	Compression strength after 7 days	Compression strength after 28 days
1	Karlshorst	German	0·61	0·68	0·62	0·67
2	Amsterdam	„	0·79	0·77	0·70	0·70
3	Bologna	„	0·55	0·60	0·33	0·37
4	„	Italian	0·46	0·55	0·38	0·46
5	Zurich	Swiss	0·82	0·88	0·66	0·81
6	„	German	1·05	1·10	0·87	1·02

The results of series 1 and 2 show a satisfactory agreement; series 3 and 4 give for the compression strengths, in particular, a very small proportion-figure for the plastic mortar, as compared with that for the rammed earth-moist mortar. This is attributable to the comparatively important differences between the individual strengths of the plastic mortars, which will be apparent from a comparison between the mean values for the two simultaneously tested groups. The series 5 and 6 differ from the rest in the high strength-values obtained with plastic mortar. This result may be due to a longer duration of the ramming process and to the care bestowed on the attainment of equal app. spec. gravity.

The German standard sand has grains of uniform size and rounded form, like the Swiss standard sand. With a plastic mortar, hand-ramming enables the sand-grains to assume positions towards each other, that are more favourable to the attainment of high degrees of strength, than is the case when the ramming is done by machinery.

The results contained in the tables only give a résumé of the somewhat important work undertaken in the various laboratories.

In 1907, Professor Canevazzi published a more detailed account of the extensive tests made in the laboratory of which he is manager, in Bologna, under the title: "Contributo a studi sperimentali di provo per gli agglomeranti idraulici".

Compared with those attained in other laboratories, the strengths determined by him showed considerable differences, and tests were accordingly made by Mr. Féret and Mr. Canevazzi with 4 series of 6 prisms each, which were made in Bologna, two of the series of tests being conducted in the latter town and the other two in Boulogne-sur-mer. From these tests it appeared, not

only that the app. spec. gravity of the prisms of one and the same series showed rather considerable differences, but also that the means of the two series varied considerably one with the other.

Series 2 : 2,171—2,215 Mean: 2,195

Series 3 : 2,202—2,233 Mean: 2,217

The differences between the strengths obtained in the two laboratories do not exceed those which showed themselves between two series tested in one and the same laboratory. Finally, when the means of the differences between the individual tests of the prisms or half prisms of each series are calculated out and general means of the strengths thus given are taken, it appears that their values expressed as percentages of such mean strengths do not show any considerable difference between one laboratory and another as regards the bending-tests, but that the compression-test results are much higher in Bologna (23 and 16 per cent) than in Boulogne-sur-mer (4 and 5 $^0/_0$). This difference is chiefly due to the circumstance that, while the apparatus for the bending test were the same in both laboratories, for the pressure tests a universal testing-machine was employed in Bologna, which was not so well adapted for these particular tests as the machine made use of in Boulogne-sur-mer.

To sum up the foregoing, the results as a whole cannot be regarded as satisfactory. Although the various testing establishments agree in regarding the prism-method as convenient and practical, it is desirable that its improvement be sought after, so that results that are in better agreement with each other may be obtained.

The chief differences are probably due to the circumstance that in the description of the process applied in Zurich we omitted to emphasize the importance of the testing of the app. spec. gravity of the prisms, which, in the application of the ordinary method with octagonal and cube-shaped samples, is always attended to.

7. Mr. Frey, Manager of the Vigier Cement Works, at Luterbach, has endeavoured to solve the problem of the uniform production of prisms, and has arrived at a satisfactory result by the expedient of filling a mould of the same content as that of a prism with standard mortar of plastic consistency and seeking to attain the app. spec. gravity of 2,17 to 2,18 by a suitable method of ramming.

This preliminary experiment fixes the quantity of the mixing water and the kind of hand work that are to be applied in each case. If the app. spec. gravity be too large, a little water must be added; if it be too small, some of the water must be removed. With a app. spec. gravity of 2,17 the mortar is very plastic, the proportion between the tensile strengths being 0,50 and that between the compression strengths 0,44 to 46. The individual results of tests on prisms made by this method agree one with another.

The tests made in the Federal Testing Laboratory in Zurich have given a similar result. With a Portland cement which shows $9^1/_2$ per cent of water for standard mortar rammed in an earth-moist condition (with Swiss sand) and 11 per cent for plastic mortar, made by the method described in my circular, a mould of $4 \times 4 \times 16$ cm can be filled with 575 gr of mortar, corresponding with a app. spec. gravity of 2·25. This figure may be attained by suitable ramming. A test with 1 or 2 prisms will show what manner of ramming is suitable, and this must then be adhered to as far as possible for all the prisms.

If a low app. spec. gravity be resorted to, such as that of 2·17 of Director Frey, the differences in the hand work may, on account of the greater plasticity of the mass, be less considerable; but on the other hand it is to be feared that the mortar will be less homogeneous.

Before the proposed comparative tests with two given Portland cements could be made in the different laboratories, the attention of the Members of the Committee was directed to the results given in the foregoing with the request that they should communicate to me their experience and views as to the best course to be taken in view of the attainment of a generally satisfactory result of the testing-method by means of prisms.

Premature tests with the same cements might lead to divergent results, which would be detrimental to the extension of a process, that, when rightly applied, gives no greater differences in the final results than do the strengths of rammed mortar, and which itself has the great advantage of simplicity.

8. Appended to this report is a supplementary table of the tests which were made in Zurich by the method given and which also give the app. spec. gravity of the block samples.

Results of the Strength-Tests of Portland Cement Mortars of 1 : 3 made by the Aid of Prisms, compared with those of the Standard Tests (Eidg. Materialprüfungsanstalt Zürich).

Portland Cement No.	Age of the Test Samples Days	Standard Mortar (rammed): Quantity of Water %	Tension: Volumetric Weight	Tension: Strength kg/cm² Max.	Min.	Mean	Compression: Volumetric Weight	Compression: Strength kg/cm² Max.	Min.	Mean	Plastic Mortar (Prisms): Quantity of Water %	app. spec. gravity Max.	Min.	Mean	Tensile Strength Max.	Min.	Mean	Compressive Strength Max.	Min.	Mean	Strength Relation to Standard Mortar: Tension	Compression
a) with Swiss Standard Sand.																						
I	7	10	2·39	16·9	14·1	16·1	2·39	169	158	166·5	$11\frac{1}{2}$	2·22	2·21	2·21	14·9	14·1	14·7	111	103	107	0·91	0·64
	28	10	2·40	23·0	19·7	22·4	2·39	233	209	228	$11\frac{1}{2}$	2·27	2·25	2·26	19·4	18·3	19·1	169	156	167	0·85	0·73
II	7	$10\frac{1}{4}$	2·36	13·2	9·0	11·7	2·37	151	132	146	$11\frac{3}{4}$	2·26	2·26	2·26	10·5	9·2	10·0	98	94	95	0·86	0·65
	28	$10\frac{1}{4}$	2·37	20·9	17·0	20·6	2·38	216	206	211	$11\frac{3}{4}$	2·28	2·26	2·27	18·6	16·2	17·8	166	157	165	0·86	0·78
III	7	$9\frac{3}{4}$	2·36	17·8	14·4	17·6	2·37	172	151	166	$11\frac{1}{4}$	2·20	2·19	2·19	13·3	11·9	12·8	107	101	104	0·73	0·63
	28	$9\frac{3}{4}$	2·38	21·6	17·8	20·4	2·38	225	212	220	$11\frac{1}{4}$	2·22	2·20	2·21	19·4	17·6	18·3	156	147	153	0·90	0·70
b) with German Standard Sand.																						
I	7	$8\frac{1}{2}$	2·33	14·0	11·3	12·4	2·36	164	133	151	10	2·28	2·27	2·28	14·1	12·8	14·0	107	104	106	1·13	0·70
	28	$8\frac{1}{2}$	2·37	21·3	15·6	20·4	2·37	201	178	192	10	2·27	2·26	2·27	18·6	17·6	18·4	157	154	156	0·90	0·81
II	7	$8\frac{3}{4}$	2·34	14·6	12·0	13·4	2·35	156	145	154	$10\frac{1}{4}$	2·28	2·26	2·26	11·1	9·6	10·5	111	101	108	0·78	0·70
	28	$8\frac{3}{4}$	2·36	19·8	16·9	18·8	2·36	229	210	220	$10\frac{1}{4}$	2·28	2·26	2·28	17·1	16·1	16·8	172	159	166	0·89	0·75
III	7	$8\frac{1}{4}$	2·33	18·3	15·4	17·3	2·32	178	152	173	$9\frac{3}{4}$	2·24	2·22	2·24	14·4	12·9	13·8	128	120	126	0·80	0·73
	28	$8\frac{1}{4}$	2·35	25·7	19·8	24·8	2·34	233	222	230·5	$9\frac{3}{4}$	2·25	2·23	2·24	21·1	18·6	20·8	186	162	180	0·84	0·78

9. These preliminary tests appeared to show the importance of improving the method, in order to obtain satisfactory results. According to the proposal of Mr. Frey, Manager of the Vigier Cement Works, at Luterbach, a solution was to be found in the expedient of keeping the volumetric weight of the fresh mortar at from 2·17 to 2·18 under all circumstances. According as the volumetric weight obtained by the first experiment turned out too great or too small, the mortar could, in order to obtain the typical figure, be mixed with a somewhat greater or somewhat smaller quantity of water.

The tests conducted in Zurich had led to the recommendation of this method, but to the proposal of a higher figure for the volumetric weight, which stands in connection with the circumstance that our staff are accustomed to a ramming-process of longer duration. Mr. Féret has tested this method and put his conclusions together in the form of a notice, which bears the title: "Vérification de la méthode de Monsieur Frey", and which was distributed among the members of the Commission in April 1908. The principal contents of this notice are here given:

A process of such simplicity, which simultaneously solves the two principal difficulties that stand in the way of the general application of the plastic standard mortar, would have such advantages, that the whole question would, by its means, be advanced a considerable step forwards, and it is very much to be wished that it may be tested in as great a number of testing establishments interested in Question No. 42, as possible. For my own part, I at once investigated it and conducted the operations in such a manner as to verify the following points, in particular:

a) In what degree does the volumetric weight of the fresh mortar depend upon the quantity of the mixing water and upon the amount of the ramming done, and what alteration results from these considerations for the strengths and for the degree of uniformity of the results?

b) Do standard mortars with different quantities of water and different ramming, but the same volumetric weight, give the same test-results with a given cement?

c) Is it possible to obtain standard mortars having the same previously-fixed app. spec. gravity (2—17 or 2·25) with all sorts of cements, and is this app. spec. gravity in every case accompanied by an admissible consistency?

In order to test this programme, experiments were made with three cements differing largely in fineness of grinding.

1 Portland cement of medium fineness of grinding with residue of 27·5 per cent on the 4900 mesh sieve;

1 Portland cement coarsely ground, in correspondence with the French booklet of requirements for marine structures (44·5 per cent residue); and finally

1 hydraulic lime of special manufacture, which on the same sieve leaves a residue of only $1^1/_2$ per cent.

These mortars were in every case composed of 900 gr of cement, and 2700 gr of sand from Leucate, which had passed through the sieve with round holes of 1,5 mm in diameter and had been retained by the sieve with 1 mm holes. It was worked for four minutes with the trowel with a variable quantity of fresh water, and the consistency was then estimated. A prismatic mould of $4 \times 4 \times 16$ cm was filled with material of the degree of density laid down for each experiment, the contents of the mould were weighed, and the 6 final prisms were produced, these having all undergone the same degree of ramming. The ramming was, as usual, performed by means of a small wooden dolly of 2×3 cm in section with rounded corners, held by two fingers without the use of force. This is to be understood as ordinary ramming. Hard ramming was applied a few times, or on the other hand the mortar was pressed into the mould with the fingers. The prisms were removed from the mould after 24 hours and immersed in water, and they were tested 28 days after production. Before the test took place, i. e. immediately after the removal of the water, they were gently dried on the surface and weighed separately, whereupon, after the pressing out of the water, their exact volume was determined by means of the Ludwig Volumometer. The app. spec gravity of the mortar at the test is obtained as the quotient of weight by volume. The bending test was conducted exactly in accordance with the directions which Mr. Schüle had given in his programme. 100 gr of shot was allowed to fall per second.

The compression tests were made by means of the Amsler-Laffon Press with the two halves of the prisms that had been broken by bending, placed crosswise between two steel plates 4 cm in breadth.

Table I.

Series No. 1 of Table II.

No. of the Prism	Determination of the apparent sp. gr. of the fracture (Prism)				Bending Tests		Compression Tests		
	Weight of the Prism	Vol of the Prism	Apparent sp. gr.	Observations	Bending-Strength	Difference from the General Mean	Strength of the Half-Prism	Difference from the General Mean	Mean Strength of a Prism
1	569·5	239·5	2·195		39·8	+ 1·2	201·5 204	+ 2·5 + 5	202·75
2	567·1	258·8	2·195		38·1	— 0·5	204 183·5	+ 5 —15·5	(193·75)
3	567·2	259·5	2·186	Minimum	(33·4)	— 5·2	170·5 212	—28·5 +13	(191·25)
4	568·8	259·3	2·194		(37·5)	— 1·1	198 199·5	— 1 + 0·5	198·75
5	567·7	258·0	2·197		38·7	+ 0·1	185·5 208	—13·5 + 9	196·75
6	576·6	262·3	2·198	Maximum	44·0	+ 5·4	214 207	+15 + 8	210·5
	General Mean		2·194	—	38·6	2·25 = 5,8% of 38·6	199·0	9·78 = 49% of 199·0	—
	Mean of the 4 highest			—	40·1	—	—	—	202·2

Table II.

No of the Series	Quantity of Water in %	Consistency of Mortar	Observations as to the Manner of Mixing and of the Ramming of the Mortar into the Mould	App. spec. gravity during Production	Apparent spec. grav. at the Test after 8 days			Strengths per cm² (Mean of the 4 Highest Values)		Mean of the Deviations in %	
					Min.	Max.	Mean	Compress.	Bending	Bending (6 Prisms)	Compress. (12 Half-Prisms)
			Finely-Ground Hydraulic Lime. (Residue = 1·5%.)								
1	11	good, rather stiff	rammed in with the fingers	2·18	2·186	2·198	2·194	40·1	202·2	5·8	4·9
2	10	too stiff	ordinary ramming	2·28	2·201	2·220	2·212	44·3	233·7	4·6	3 1
3	11	good, rather stiff	» »	2·30	2·248	2·263	2·254	51·0	269·4	3·4	2·3
4	12	good	» »	2·26	2·202	2·220	2·207	44·0	220·1	3·2	3·0
5	13	too soft	» »	2·20	2·148	2·158	2·154	37·2	150·2	3·5	2·0
			Portland Cement of Medium Fineness. (Residue = 27·5%.)								
6	8	too stiff	ordinary ramming	2·18	2·209	2·225	2·216	29·3	127·3	4·5	3·3
7	9	good	» »	2·20	2·204	2·211	2·208	34·6	146·4	7·6	4·8

8	9	good, rather stiff	Produced 7 days later than series 6, 7, 13, 14, and 15	Same Assistant ordinary ramming	2·20	2·182	2·200	2·191	30·9	128 9	3·7	3·6
9	9	» » »		Another Assistant (for this series only) ordinary ramming	2·20	2·198	2·206	2·201	30·7	133·3	5·4	4·4
10	9,5	good		» »	2·205	2·185	2·206	2·192	28·4	132·6	8·2	3·8
11	10	»		rammed with fingers	2·205	2·172	2·187	2·179	30·7	134·4	4·6	4·8
12	10	»		ordinary ramming	2 24	2·188	2·199	2·191	29·3	128·3	6·1	3·7
13	9	»		harder ramming	2·23	2·229	2·254	2·240	39·7	163·4	3·2	3·9
14	10	good, rather soft		ordinary ramming	2·18	2·168	2·184	2·177	32·0	123·6	4·4	4·8
15	11	rather soft		» »	2·16	2·137	2·147	2·143	30·6	121·1	4·9	3·5
			Coarsely-Ground Portland Cement (Residue = 44·5 %.)									
16	10	good		rammed with fingers	2·14	2·090	2·100	2·093	19·3	65·4	6·4	5·5
17	9	rather stiff		ordinary ramming	2·185	2·158	2·182	2·170	20·8	88·9	5·9	3·3
18	9	» »		harder ramming	2·20	2·179	2·193	2·188	22·8	107·1	5·7	2·8
19	10	good		ordinary ramming	2·22	2·139	2·152	2·145	25·2	97·7	3·7	4·3
20	11	rather soft		» »	2·18	2·132	2·138	2·135	22·8	79·5	5·8	3·6
						Mean of the 20 series:					5·0	3·6

In order to determine the degree of agreement between the results given by each series of 6 prisms, the means of the 6 bending strengths and of the 12 compression strengths were respectively computed; the differences between the invidual strengths and these means were determined, and the means of these difference again, as functions of the mean strengths, were expressed in hundredths.

On the other hand, to enable the mean strengths to be compared one with another, the mean of the 4 highest strengths of each series of 6 prisms was taken into account, in accordance with the programme of Mr. Schüle, after the mean of the strengths of each prism had been determined from the figures for the two halves, for the pressure.

Table I gives the results of these individual strengths for the I series of 6 prisms.

In general, the smallest and greatest strengths in each series correspond with the smallest and largest volumetric weights. Exceptions, however, are of pretty frequent occurrence.

Table II gives the circumstances of the production of the individual prisms, their consistency, the app. spec. gravity ascertained in the mixing process, and the mean results calculated in the manner explained above.

The principal conclusions to be drawn from the above are: —

a) The app. spec gravity are not the same after 28 days as those at the production of the samples, although it may in both cases be assumed that the latter are saturated with water; they are generally somewhat smaller, but vary in the same sense. The determination of the app. spec. gravity of the mortar in process of being mixed appears to be less exact than that of the mortar when set.

b) With one and the same cement the app. spec. gravity of the mortar may vary within pretty wide limits according to the quantity of the mixing water used and to the degree of the ramming. With given ramming, the app. spec. gravity rises at first with the quantity of water, reaches a maximum when the consistency is neither too stiff nor too thin, and falls again for larger quantities of water. The rule given by Mr. Frey, by which a given app. spec. gravity is obtained only in conjunction with an alteration in the quantity of the water, is applicable only to mortars which are

produced in softer consistency than that corresponding with the maximum of the app. spec. gravity.

c) The maximum of the app. spec. gravity of the mortars with equal ramming varies with the cement, and it appears difficult to establish a typical app. spec. gravity that corresponds with an admissible consistency with all possible cements. The mortar, 1, 14, 17, or 20, all of which in their fresh condition have a app. spec. gravity approximately equal to 2·18, might perhaps fulfil the condition. The proof, however, is wanting, that all cements of this app. spec. gravity will give an admissible mortar, and further investigations in this direction would be necessary. Later experiments have shown me that the German standard sand gives a somewhat smaller app. spec. gravity than the sand from Leucate.

d) The bending and compression strengths increase at a rate that is parallel with that of the increase of the app. spec. gravity. The proportion is also fairly regular, even when the app. spec. gravity of the set mortars are taken into account. An insight into these conditions is obtained by means of diagrams, when, for various mortars with a given cement, points are set off, which have the app. spec. gravity as abscissae and the strengths as ordinates. When the unavoidable errors in the process of investigation are taken into account, the strengths of the mortars with given app. spec. gravity with the same cement show large with differences when mixed with different quantities of water and different degrees of ramming.

e) Even we had, at the outset, been able to believe that the thinnest mortars would be the easiest to ram, and that strengths would thus show themselves in each series which would agree better among themselves, the facts show, that the relative deviations from the rule of the individual results for the various mortars, as computed from the means, vary in a quite irregular manner. The conclusion must here be drawn, that, in one and the same laboratory and within the limits within which the experiments were made, the degree of agreement of the strengths obtained with the 6 prisms of each series is almost independent of the composition of the mortar.

In conclusion Mr. Frey's method in its present form does not appear calculated to provide a solution of the double problem

that was set for consideration, and fresh investigations would have to be undertaken in order to put the method on a more exact footing. It may, indeed, be questioned, whether, with given ramming, the proportion of the mixing water cannot be set down as that corresponding with the maximum app. spec. gravity. It would, in every case, be desirable that each of the members of Committee No 42 should make investigations of his own in order to discover the best solution of the problem, for the success of their work above all depends upon this.

We need not, it may be observed, be appalled at the rather considerable differences appearing under different conditions in the foregoing experiments between the strengths of the mortars, or be led to base arguments upon them against the adoption of the plastic mortars The rammed mortars show differences that are no less considerable, when they are not produced under identically the same conditions, and we saw, some years ago, how comparative experiments in a number of German laboratories with rammed mortar made with the same cement, the same sand, and the same ramming apparatus, gave greatly differing strengths.

10. In addition to the work of Mr. Féret, Mr. Petersen has carried out some experiments in the testing laboratory in Copenhagen on the method set forth in the President's circular, with the object of determining the influence of the ramming with 60, 80, and 100 strokes per minute. In his communication he mentions that it would be of interest to simplify the determination of the ramming of the mortar by laying down the rule that a rammer is not to be used, but that the mortar is to be pressed in by hand alone.

Mr. Féret's Table II shows that this method of production gives individual differences which are greater than in the other one

11. Such being the state of the question, it could not be of any use to distribute samples of the same cements among the different laboratories. The results would not be certain, since doubt still exists as to the best method of determining the quantity of water and the work of ramming. Mr. Frey had this problem investigated afresh in the laboratory of the cement-works of which he is manager, and he was led to propose a new method for the production of the block-samples, which after being discussed in Basle

with Mr. Féret and the President of the Committee in October, 1908, was tested with a number of cements in the Federal Testing Laboratory in Zurich, and which is used as a check on the daily work of manufacture at Luterbach. The following arguments in establishment of this method are taken from a notice supplied by Director Frey: —

We had on various occasions established the fact that the results of the prism-method become more regular when no water is allowed to trickle through at the lower part of the mould, and have accordingly tried to prevent this or to reduce the leak to a few drops. On the other hand it was our endeavour to attain a constant app. spec. gravity, since the strength varied with this latter. The app. spec. gravity of the prism after its production is altered by its being kept immersed in water to the greater extent the more porous the mortar. The prisms, the increase of weight of which is abnormal, should accordingly be left out of account in the calculation of the results.

Now instead of the quantity of water being so regulated that the same ramming and always the same app. spec. gravity are attained, a certain quantity of water can be kept constant, and in each case the same weight, sand, cement, and water required for the exact filling of the 6 divisions of the mould may be made use of. The constant app. spec. gravity will then be attained under the condition that no water shall escape from the lower part of the mould. The ramming work will differ somewhat, according to the binding-medium used; but this presents no difficulty, if care only be taken that the mortar be made as plastic as possible by working. With Swiss standard sand we have chosen the proportion "11 per cent of water", and the plasticity attained might seem to vary to a considerable degree with the cement. The experiments undertaken have shown that very different qualities of Portland cement may be worked up witth this quantity of water without difficulty, and give the same app. spec. gravity for the prisms.

The employment of a constant quantity of water seems to be in opposition to the ordinary method, which seeks to attain the same degree of consistency by means of the variation of the quantity of water in the standard mortar. There are good reasons, however, for questioning the suitability of these variations. Indeed,

since the sand is always the same, only the nature of the cement has an influence on the quantity of the water. A coarsely-ground cement will usually require less water than a finely-ground one. so that the strengths of the former will, in comparison with those of the latter be the greater; on the other hand it would appear that there should be a simple proportion between the quantity of water which is used for the standard consistency in the setting test and that of the standard mortar of 1 : 3. This, however, is not the case, as may be seen when the standard quantities of water for the pure cement and for the standard mortar, respectively, are compared with one another. With Swiss Portland cement the former will vary between 34 and 23 per cent and the latter between 9,5 and 10 per cent, and this in a quite irregular manner. For these reasons it would be an advantage to depart from the principle of the same consistency of the mortar, and, for the filling of the mould, in every case to make use of the same quantity of fresh mortar with a never varying proportion between cement, sand, and water.

It becomes necessary, then, to fix the quantity of the water in such a manner that it will be possible to fill the mould and ram the mortar without leakage occurring at the bottom. The proportion of 11 per cent, which was in general attained with Swiss standard sand on the application of the method set forth in the circular of the President, is found by experience to accord with the conditions above laid down.

The question of the quantity of the water with other standard sands then, remains for solution. In the case of mortar of 1 : 3 with Swiss standard sand, the theoretical quantity of water necessary for the attainment of a compact mortar that exactly fills the hollow spaces in the sand, is 9·5 per cent, i. e. 1·5 per cent less than for the plastic mortar. For the German standard sand this calculation would give 10 per cent of water in place of the 11 per cent with the Swiss standard sand. In this respect further experiments are necessary.

12. The new method would replace the one given in my first circular and points II and III would have to be altered in the following manner: —

The Frey, Proposal for the mixing of mortar and the production of prisms.

II. Mixing of the mortar. For the simultaneous production
f six prisms:

2340 gr	German	standard sand	780 gr	cement	= 3120	gr	or
2280 „	Swiss	„ „	760 „	„	= 3040	„	„
2370 „	French	„ „	790 „	„	= 3160	„	

re to be simultaneously mixed together in a shallow vessel
ry, following which,

with	German	standard sand,	10 per cent	= 312 gr	of water	or
„	Swiss	„ „	11 „ „	= 334 „	„ „	..
„	French	„ „	10 „ „	= 316 „	„ „	

s to be poured on in two portions; the mortar is to be thoroughly vorked till it is as plastic as it can be made.

III. Production of prisms. For one prism one sixth of his mortar is weighed out and rammed into the mould, half at time, with an iron pestle of 1 kg in weight and of 3×3 cm tamping-end surface. To begin with, the mass of mortar is rammed nly to such a degree that it goes into the mould and stands omewhat above it. Not till all the six divisions of the mould are hus filled, is the ramming completed, care being thereby taken: —

1. That, as a sign of complete binding, the slime formation n the tops of the individual prisms has taken peace, and

2. that no water, or not more than a drop here and there, ppear at the bottom of the mould on the completion of the amming.

After being kept for 48 hours in moist air, the mould is aken asunder, and the prisms are kept under water until just efore the test.

The Members of the Committee have been invited to examine hese altered methods, and it is to be wished that at the next neeting of the Congress it may be possible to base the discussion pon completed experiments, so that a uniform method for the esting of cement may be arrived at.

It is scarcely probable that the hydraulic limes can be tested n the same manner; for it is, above all things, a uniform method or the testing of cements and especially of Portland cements, that s required.

The conclusions which can at this stage be drawn by the Reporter from the experiments made, may be summarized in the following manner:

1. The testing of cements by means of prisms made from plastic mortar, is distinguished by its extreme simplicity and by the great advantage, that both bending and compression tests can be obtained from the same block-samples. This testing process is the solution of the question as to equal capacity of the tensile and compression test samples.

2. The individual differences compared with the mean, are smaller by this method than by the use of tensile test samples of 8 shape. For compression tests, there is no considerable difference between the individual deviations and the mean values given by the results with cubes or with prisms.

3. The smaller strength figures given by the prism method correspond better with the strengths which have to be dealt with in practice, than do the high degrees of strength of mortar of earth-moist consistency subjected to hard ramming.

4. The difficulty of exactly determining the mixing-water and the work of ramming is solved in a satisfactory manner by the Frey proposal, which consists in the exact filling of the 6 divisions of the mould without the separation of water, so that with every cement the same weights of the latter, of the sand, and of the water are used, in order in this way to attain the same app. spec. gravity of the test samples with fresh mortar.

5. Finally, the testing method with prisms gives the compression tests the importance which they deserve, and which far exceeds that of the tensile and bending strengths, whether by reason of their regard to regularity or of their practical importance.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS
Vth CONGRESS, COPENHAGEN 1909.

II1

HARDNESS TESTS.

Official report by Dr. techn. **P. Ludwik**, of Vienna.
(Translated from the German by Dr. H. Borns, London.)

The discussion of hardness tests by the Brussels International Congress for Testing Materials of 1906 brought out the fact that, of the many, scientifically often most interesting methods, — e.g. those of Hertz-Auerbach-Föppl[1]), Haußner[2]), Kick[3]), Kirsch[4]) and Martens[5]) — the ballpressure tests alone seemic to have been introduced into technical practice in a greater extension.

For this reason — and on account also of the limited space at my disposal — I shall confine myself to a review of these tests

[1]) „Zeitschrift d. österr. Ingenieur- u. Architekten-Vereines", 1907, Nr. 11 u. 12.

[2]) Haußner has shown that the hardness depends equally upon the compression limit and the resistance to shearing (comp. Note 35), and he defined hardness as the resistance to planing per mm² for a cutting angle of 90⁰. („Österr. Zeitschrift für Berg- und Hüttenwesen", 1892, Nr. 32 und 33)

[3]) Kick measures the hardness by the resistance to shearing, presuming that the specimen is as tightly enclosed as possible on all sides. („Zeitschrift des Österr. Ingenieur- und Architekten-Vereines", 1890, p. 1.)

[4]) Kirsch determines the hardness from the specific load (in kg/mm²) required to force a cylindrical steel plunger of 5 mm diameter by 0,01 mm permanently into the material. The depth of penetration is ascertained with the aid of a mirror apparatus. (Mitteilungen des k. k. technolog. Gewerbemuseums, Vienna, 1891, p. 108.)

[5]) Martens measures the scratch-hardness by the load (in grammes) under which a conical diamond (apex anglo 90⁰) produces a scratch 0,01 mm in width. (Sitzungsberichte des Vereines zur Beförderung des Gewerbefleißes, 1889, p. 197; Mitteilungen aus den kgl. technischen Versuchsanstalten zu Berlin, 1890, p. 215.)

and of some, then still unknown methods, the cognate cone-pressure tests.

A. Ball-pressure Tests.

They are applied in determining the hardness of plastic materials such as iron and steel.

In the original Brinell test[6]) a hard ball of steel is forced by quiet pressure into the material to be examined, the diameter of the spherical impression is determined, as a rule with the aid of a special microscope, and the area of the cavity is calculated. The quotient of pressure (in kg) by the area (in mm²) is Brinell's Hardness Number *H*.

According to the researches of Ast[7]), Benedicks[8]), Breuil[9]), Brinell[10]), Le Chatelier[11]), Dillner[12]), Leon[13]), Malmström[14]), E Meyer[15]), Rejtö[16]) and others, this hardness number is influenced by the size of the ball and by the load; smaller balls at equal loads, and greater loads with equal balls yielded greater hardness numbers.

Figs. 1 and 2, exemplify the dependence of the hardness number (for balls of 10 mm diameter) upon the diameter of the impression circle and the magnitude of the load respectively. Fig. 1 concerns annealed tool steel[17]); the abscissae are the diameters *d* of the impression circles, the ordinates the corresponding

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[6]) Compare: P. Ludwik: „Über Härtebestimmung mittelst der Brinellschen Kugeldruckprobe und verwandter Eindruckverfahren", „Zeitschrift des österr. Ingenieur- und Architekten-Vereines", 1907, Nr. 11 und 12 (Nr. 12, p. 205 extensive literature references).

[7]) Brussels Intern. Congress, 1906, Report on Problem 2, p. 18.

[8]) „Recherches physiques et physico-chimiques sur l'acier au carbone." Upsala 1904.

[9]) „Essais de divers métaux par la méthode de Brinell." Congrès de Bruxelles 1906, Rapport non-officiel.

[10]) „Baumaterialienkunde", 1900 and elsewhere.

[11]) „Revue de Métallurgie", 1906, Nr. 2.

[12]) Brussels Intern. Congress, 1906, Report on Problem 27.

[13]) „Stahl und Eisen", 1907, Nr. 50, p. 1820.

[14]) „Dinglers polytechn. Journal", 1907, No 3, pag. 34.

[15]) „Zeitschrift d. Vereines deutscher Ingenieure", 1908, Nr. 17, 19, 21 and 52 (add.). (Also „Physikal. Zeitschrift", 1908, Nr. 2.)

[16]) „Baumaterialienkunde", 1907, Nr. 17/20.

[17]) See Note 6.

hardness numbers H. The dotted curves of Fig. 2 concern steels containing from 0.08 to 1.13 percent of carbon; the abscissae are the loads up to 5 tons, the ordinates again the H.

Since this dependence of the hardness number upon the pressure would influence not only the absolute values of the numbers, but even their sequence, Brinell suggested to fix the loads, recommending 3000 kg for iron and steel and 500 kg for other metals and alloys; the size of the balls to be 10 mm in both cases.

But equal loads produce different cavities in material of different hardness (shallow cavities in hard substances, hemispherical cavities in softer substances), and hence also

Fig. 2.

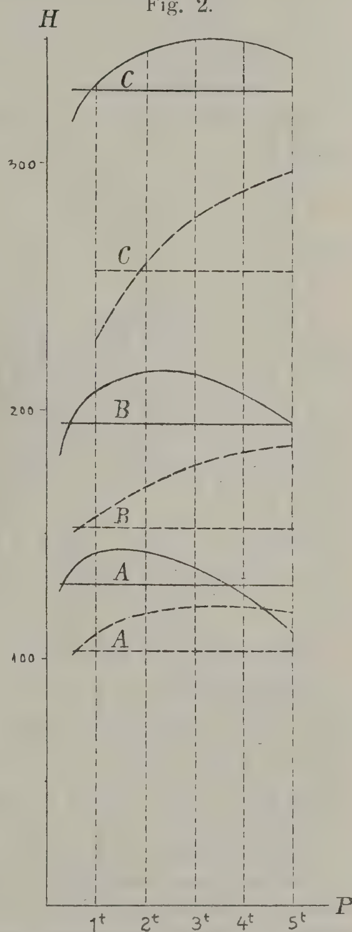
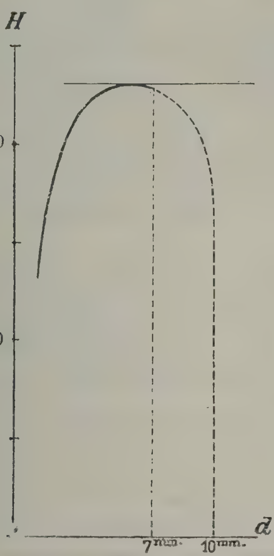


Fig. 1.



different cold work "flow phenomena"). The two effects in fact hardly admit of direct comparison. This particularity of the Brinell test becomes especially striking, when comparative tests are made on specimens of strongly differing hardnesses; while it may practically not make itself felt at all, when the specimens are of fairly

equal hardnesses, e. g. in homogeneity tests and in the control tests of iron and steel processes.

Quite recently E. Meyer[18] has proposed to refer the hardness number not to the unit area of the spherical cavity, but to the unit area of the impression circle, as only the latter had a „physical significance".

In practical application this method labours under the disadvantages that in the first place, it accentuates the justmentioned defect of the ball test which E. Meyer[19] himself emphasises, and in the second instance, that it excludes one frequently very appropriate way of conducting this test, by the determination of the depth of the cavity[20]).

In my opinion the Brinell test might, in many technical applications[21]), be improved by making the angle α not smaller

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18) See Note 15.

19) The experiments of E. Meyer (Zeitschrift des Vereines deutscher Ingenieure, 1908, No 17, 19, 21, 52) show that the load P may, within wide limits, very well be expressed as a function of the diameter of the impression circle, d analogous to Föppl's pressure cylinder method, the equation being $P = a\,d^n$ where a is proportional to the hardness, and n ranged from 1,91 to 2,38; for the cone test n is always 2. According to E. Meyer therefore, "the hardness quality of a substance can, in the ball test, not be expressed by a single quantity, and the statement of a single hardness number for a certain load, even if the load be generally agreed upon, is merely a practical expedient, with which we may often be satisfied. however. When we wish to investigate the behaviour of a substance with the aid of the ball-pressure test, the constants a aud n must be determined by about 5 experiments at different loads."

20) When the diameter of the impression grows from 1 to 8 mm, the hardness number referred to the area of this circle would in the case of grey cast iron increase by about 130 % e. g. (compare „Zeitschr. Verein deutsch. Ingen.", 1908, pages 646 to 651). In order to compensate so far as possible for the variation of the hardness number with the dimensions of the impression, Brinell has referred the hardness number to the area of the cavity, and not of the impression circle (the latter would have been natural, since he measured the diameter).

21) With materials that are not too hard; because otherwise better defined (less shallow) impressions would involve a rapid wear of the ball, while shallow impressions might lead to errors in the depth measurement. For this latter reason ball tests by depth measurement are in general not advisable (except when the A. Martens apparatus presently to be mentioned is used) for narrow or thin specimens and in cases, where the determination of the surface hardness is the chief object, or when the test piece should not be damaged more than can be helped.

The objection has ben raised that sharp impressions should in so far be less suitable than shallow ones, because in the former case we do not determine

than 90^0, but somewhat greater than 90^0 (compare Fig. 3). The spherical area f would, in that case, not subsequently be deduced from the diameter of the impression circle, but at once (excluding the marginal extrusion) from the depth t of the cavity (compare Fig. 3), the formula being $f = \pi D t$ in which D is the diameter of the ball. The impression will approximately be of the same size, but more sharply defined, and the operation will be quicker, while equally accurate. A very simple instrument for determining the penetration, applicable both for ball and for cone tests, will be described in the next section; the instrument admits of determining, expeditiously and easily, depths up to 5 mm within 0.01 mm. In examining iron and steel by this method, $^1/_4$" balls should be applied, lest the impressions become too shallow, or too large loads and specimens be required.

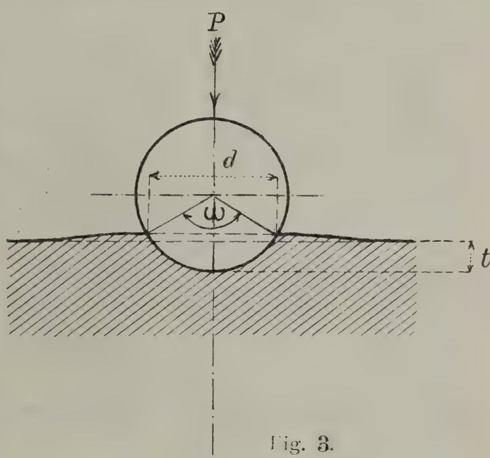

Fig. 3.

It should be pointed out that measurements of the diameter — and of the depth — frequently yield very different hardness numbers and even series of figures in different sequence, owing to the marginal extrusion and the different character of the impressions; the former method requires weaker impressions, the latter on the whole stronger impressions (compare note 21). This feature is drastically brought out by the deviation of the dotted curves from the full-line curves of Fig. 2. The dotted curves have already been explained. The full-line curves concern the same materials and

the hardness of the original material, but of the material altered by being strained in the cold. This objection does not, in my opinion, appear to the point. I should, on the contrary, consider this alteration as advantageous in many cases, because the resulting flow phenomena resemble the conditions of scratching and of woking with tools. When the impressions are very shallow, moreover, the accidental condition of the surface, which is much influenced by external circumstances, will affect the hardness and make the test a less reliable and more arbitrary criterion of technical quality.

the same loads; but the hardness numbers have been deduced from the depths of the cavities (instead of from the diameters) and refer to $^1/_4$" balls (not to 10 mm balls).

For the exact measurements of very small cavity depths (up to 0,6 mm) A. Martens[22]) has constructed a ball apparatus, which allows of determining differences of 0,01 mm with a degree of accuracy which no other apparatus approaches. Experiments conducted by A. Martens and E. Heyn[23]) show that, with balls of 5 mm diameter, the ratio between load and depth of cavity may be regarded as constant within the depth range of 0,05 mm. Martens, therefore, determines the hardness from the load which is required to force a ball of 5 mm to a depth of 0,05 mm into the specimen. The applied pressure (up to 2500 kg) is the hydraulic pressure of any water main (to which the apparatus is directly joined). Want of space prevents my entering into details of this exceedingly interesting instrument of A. Martens (compare the Congress paper by A. Martens and E. Heyn).

As regards the testing of specially hardened steels I should particularly refer to the fundamental researches of Rasch and Stribeck[24]). Stribeck has also dealt at length with the influence which adhesion and the differences in the hardness of the two bodies which are pressed against one another (ball against solid sphere, hollow sphere, or plane plate) exercise upon the mean compression in the contact surface which is defined as the pressure-hardness ("Druckhärte").

For wood testing G. Janka[25]) has modified the Brinell test in such a manner that he determines the pressure required to force a hemispherical ball of steel (1 cm^2 sectional area), fixed to the

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22) Sitzungsberichte der kgl. Akademie der Wissenschaften, Berlin, 1905, S. 1035. Verhandlungen des Vereines zur Beförderung des Gewerbefleißes vom 5. März 1906. „Z. d. V. d. I.“, 1908, S. 1719.

23) A. Martens und E. Heyn: „Vorrichtung zur vereinfachten Prüfung der Kugeldruckhärte und die damit erzielten Ergebnisse“, „Z. d. V. d. I.“, 1908, S. 1719.

24) E. Rasch: „Prüfung von Gußstahlkugeln“, „Zeitschrift für Werkzeugmaschinen und Werkzeuge“, 1899, No 19 and 20.

R. Stribeck: „Prüfverfahren für gehärteten Stahl unter Berücksichtigung der Kugelform“, „Z. d. V. d. I.“, 1907, 1445, 1500 and 1542.

25) G. Janka: „Die Härte des Holzes“, „Mitteilungen der k. k. forstlichen Versuchsanstalt in Mariabrunn“, Wien 1906, Wilhelm Frick.

pressure plate, completely into the wood under examination. The suddenly accelerated rise of the pressure gauge indicates the moment, when the ball has entirely been embedded[26]).

The method of Shore[27]) differs in principle from those so far mentioned. He deduces the hardness from the height of resilience of a hard steel ball which falls from a certain height upon the plane surface of the specimen. Shore's hardness numbers are influenced by the elasticity of the material.

B. Cone-Pressure Tests.

The cone-pressure test marks a transition from the ball-pressure methods to scratch methods. It is the outcome of efforts to simplify the Brinell test with the further object of making the hardness number independent of the load and of the dimensions of the impression. The cause of this dependence, we conclude directly from Kick's law of proportional resistances, is merely the geometrical dissimilarity of the impressions produced. Hardness numbers always independent of the load can only be realised, if the impressions remain geometrically similar for all loads. That will be so when the ball is replaced by a cone. This is the leading idea of the recently proposed cone-pressure test[28]).

The "cone-pressure hardness" $\left(\frac{P\,kg}{f\,mm^2}\right)$ of a material is defined as that pressure P in kg per mm² of permanent impression (area $f = \pi \frac{d^2}{4} \sqrt{2} = 1.11\ d^2 = 4.44\ t^2$, compare Fig. 4) which is required to force a cone of apex angle $\alpha = 90^0$ normally to any

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[26]) After concluding this report G. Janka published further experiments which elucidate the relations between the ball-pressure and the cone-pressure hardness on the one hand, and on the other hand the strength, density and hardness of various woods („Über Holzhärteprüfung", Mitteilungen der k. k. forstlichen Versuchsanstalt in Mariabrunn, Vienna 1908, W. Frick.)

[27]) See "American Machinist", 1907, Nov. 30., p. 747/51, 1908, May 16., p. 675/78 and Nov. 28., p. 709/10. 1909, March 6, p. 222/28.

[28]) P. Ludwik: „Über Härtebestimmung mittels der Brinellschen Kugeldruckprobe und verwandter Eindruckverfahren", „Zeitschrift des österr. Ingenieur- und Architekten-Vereines", 1907, No 11 and 12 and „Baumaterialienkunde", 1907, No 8 to 10. P. Ludwik: „Die Kegelprobe, ein neues Verfahren zur Härtebestimmung von Materialien", Berlin 1908, Julius Springer.

depth into the material. The area of impression is deduced, during the test, by measuring the depth. The subsequent measurement (by means of a special microscope) of the Brinell impression is hence dispensed with, and the operation is all the more simplified, as it is possible to make several determinations during a single penetration; thus a mean value is obtained.

Wen the hardness is derived from the diameter of the impression (not from the depth), the resulting hardness numbers must likewise be independent of the load[29]), although they might eventually (owing to the different development of the marginal extrusion in different materials) lead to different sequences.

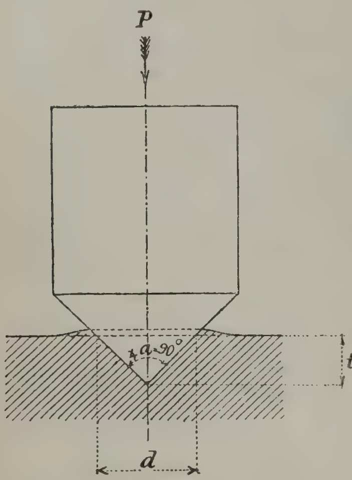

Fig. 4.

In Fig. 2 the full straight lines indicate, for the materials stated, the cone-pressure hardness numbers as deduced from the depths of the impression, and the dotted straight lines indicate the values as deduced from the impression diameters.

The depth measurement is more expeditious and more-over applicable even for materials which do not show welldefined impression margins. The diameter measurement is hence preferable only, when small impressions have to be used, since in that case the measurement of the depth may be inexact owing to faulty adjustment of the zero, because the point was rounded off, the cone not completely balanced, or applied under impact; considerable errors might arise in this way.

The firm of J. Amsler-Laffon & Sohn, of Schaffhausen, Switzerland, supplies special instruments for these cone tests, as suggested by the author; the apparatus may directly be combined with the press of any Brinell ball-test instruments.

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[29]) This follows directly also from the fact experimentally confirmed by E. Meyer that the marginal extrusions remain geometrically similar with different loads. (Compare „Zeitschr. d. Vereins deutsch. Ingenieure“, 1908, No 52, p. 2077.)

In the Amsler-Laffon instrument a cylindrical steel centre-punch, plane above, ground to a right-angled cone below, is vertically mounted in a casing of bronze, in which it is free to turn; it is balanced by a lateral spring. The displacement of the cone (with regard to the casing) is transferred to a pointer by the intermediation of an elastic threaded bushing and a toothed wheel; the pointer allows of easily reading depths up to 5 mm within 0,01 mm, as was already stated. The pointer is accurately adjusted by turning it with the aid of the milled edge of the bushing, in case the top of the specimen should not be perfectly plane. The cone can easily be exchanged and be re-ground. The whole instrument weighs 0,7 kg ($1^1/_2$ lbs, and its height, reckoned from the upper pressure plate to the surface of the specimen, is about 10 cm (4″).

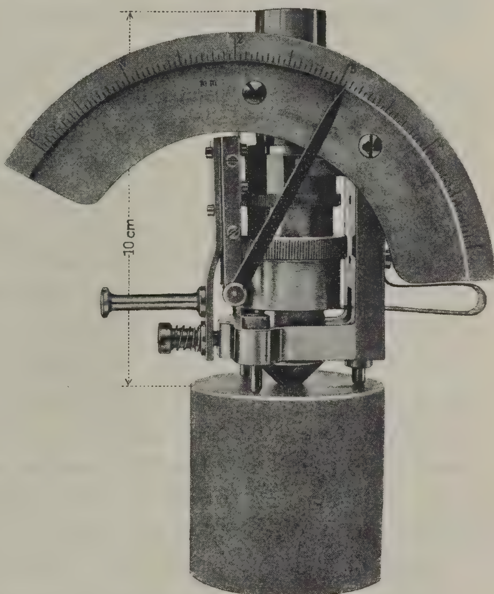

Fig. 5.

Further information will be found in the book „Die Kegelprobe“ [30]), in which the method of conducting the test, the influences of the cone-inclination and of blunt points, the relation between cone-pressure hardness and yield point of iron and steel, the cone-impact test, and other features are fully discussed.

When the conical punch is replaced by a cylinder, to the lower end of which a ball is fixed (by means of wax or a spring), this instrument can also serve for ball-pressure tests. The hardness number then results from the depth in mm (read after taking-off

[30]) P. Ludwik: „Die Kegelprobe, ein neues Verfahren zur Härtebestimmung von Materialien“, Berlin 1908, Julius Springer.

the load) and from the formula $H = P/\pi D t$, where P is the load in kg, and D the ball diameter in mm.

The ranges of applicability of the ball and cone instruments are, on the whole, the same. For very hard materials the ball test will be preferable, as the ball is more durable than the conical point; with brittle materials the cone test will deserve preference, as it resembles the scratch method and can be applied where ball tests would fail.

C. Relations between the Ball-Pressure Hardness and the Cone-Pressure Hardness and the Strength of Metals.

The question, whether the hardness numbers of a material, obtained by these two methods, admit of any general conclusions respecting the strength of the material, and in particular the yield point and the "tensile strength", is of high practical interest. If the directly applicable and inexpensive hardness tests could replace the expensive testing on machines which necessitate elaborate preparation of the specimens, a considerable advantage would have been gained, especially as regards the commercial testing of iron and steel.

As there is no time for discussing these important and far-reaching problems, I shall only allude to the practical results of some of the respective researches[31]). A direct constant relation between yield point and tensile strength on the one side, and hardness (as determined by ball or cone tests) on the other, can not exist, since that relation would, among other factors, depend upon the shape of the impression and of the stress-strain diagram[32])

[31]) Comparative tensile tests and ball tests were conducted by Ast, Breuil, Brinell, Charpy, Dillner (Brussels Congress, 1906), Kürth („Zeitschr. d. Vereines deutsch. Ingen.", 1908, No 39 and 40). H. Le Chatelier (Revue de Métallurgie 1906, No 2), Leon (Stahl und Eisen, 1907, No 50) and others.

As regards the relations between hardness and extension, compression, and torsion diagrams, compare P. Ludwik, „Über die Grundlagen der technologischen Mechanik", „Österr. Wochenschrift f. d. öffentl. Baudienst", 1908, No 42 p. 762.

[32]) An inflection near the yield point suffices to affect the former relation. Compare A. Leon, „Über die Beziehung der Kegeldruckhärte zur Streckgrenze bei Eisen und Stahl", Stahl und Eisen, 1907, No 50.

The relations between hardness and yield point will, particularly with shallow impressions, be less dependent upon the stress-strain curve, of course, than the relation of hardness to tensile strength, compare note 35.

This dependence explains also, why A. Kürth, when determining the hardness of stretched copper rods, found with shallower ball impressions and

and, in the case of the tensile strengh and hardness of materials which do not contract (non-ductile), also upon the cohesion[33]).

This admission does not, howewer, at all exclude the possibility of deducing from the hardness number — with the aid of a coefficient which will only hold for the respective groups of similar materials — the yield point and the tensile strength with an approximation which will frequently be sufficient for practical purposes[34]).

It should, moreover, be pointed out that for materials which undergo contraction — that is to say, for most metals (compare Note 33) — the "tensile strength" can not really claim that importance as a quality criterion which is at present ascribed to it, especially by metallurgists. The „tensile strength" gives, for such materials, frequently not even approximately the maximum specific breaking stress of the material (the latter is, in the case of mild steel, nearly twice the test value) but merely — like the impression hardness and scratch hardness[35]) — a mean specific shearing resistance, which is moreover

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larger elongations (and therefore a more uniform type of "flow curve") a more satisfactory agreement between the variations of the hardness and the yield point, than with deeper impressions and smaller elongations. (Zeitschr. Verein deutsch. Ing., 1908, Nr. 39.)

Since with continued working of a material in the cold the relation of the yield point (which will be raised) to the tensile strength varies, the relation of hardness to tensile strength must necessarily likewise be influenced by the drevious treatment in the cold. (Compare ibid. 1908, No. 40.)

[33]) In materials which do not contract (non-ductile materials) the tensile strength is materially influenced by the cohesion; in (ductile) materials which contract, the cohesion is only overcome after the maximum load has been reached; in the latter case, therefore, the two quantities are independent of one another.

[34]) For instance, with railway rails. The Prussian Railway Department stipulates for rails of a minimum tensile strength of 60 kg/mm² (38 tons per sq. inch) with balls of 19 mm (3/4 inch) diameter and 50 tons loads, impression depths of from 3,5 to 5,5 mm, for rails of a minimum tensile strength of 70 kg/mm² (44,5 tons per sq inch) impressions depths ranging from 3 to 5 mm. Breaking tests and ball tests have to be made in equal numbers. (Zentralblatt der Bauverwaltung, 1908, No. 77, p. 520.)

[35]) Every permanent change of shape is due to a permanent relative displacement of the particles. The displacement is opposed by the „internal friction" which is to be regarded as a specific resistance to shearing. The higher the initial friction, the harder the "original" material. The more the friction increases with the specific shear, and the steeper therefore the flow curve, the more intense will be the cold hardening which the material will undergo with increasing deformation, and the greater will be the deformation resistance to a continued

essentially affected by the rate of increase of the resistance to deformation with the elongation (the shape of the "flow curve").

It would therefore appear advisable to substitute, in many cases of contracting (ductile) materials, the much simpler and cheaper ball-pressure and cone-pressure hardness tests for the tests which exclusively yield the tensile strength.

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working in the cold. (Compare P. Ludwik "Über Grundlagen der technologischen Mechanik", „Österr. Wochenschrift f. d. öffentl. Baudienst", 1908, No. 42, p. 763.)

This view concerning the hardness problem seems very well to express the difference in principle existing between the various methods of hardness tests for plastic materials. Thus, for instance, the elastic limit and the yield point (method of Kirsch) measure the resistance to shearing resulting at minimum specific shear stress, and the shearing strength (method of Kick) measures the maximum specific shear stress; in the former case we deal with the minimum or original hardness, in the latter case (theoretically at least, under pure shear) with the maximum hardness. With the "impression-methods" we always find a mean specific resistance to shearing, since the locally produced specific shear strains will differ according to the shape of the impression. The specific shear resistances (internal friction) which are called forth will all the less deviate from one another, the shallower the resulting impression and the "flow curve" of the material. All the less consequently, the "impression hardness" will differ from the "original hardness". (Compare also P. Ludwik „Über Zähigkeit und Schmeidigkeit", Zeitschrift für Werkzeugmaschinen und Werkzeuge, 1908, No. 23, p. 329.)

The circumstance, that the yield point is observed under a uni-directional stress, whilst the "impression hardness" is observed under stresses in all directions, appears to me to be of minor importance for this question in the case of plastic materials, since the internal friction seems relatively little to be influenced by the normal stress within the range of the stresses to be considered in this connection.

That brittle materials in particular, when under stresses distributed in all directions about an axis, may appear to behave in an essentially different manner than when under ordinary tension and compression tests, as Kick has so beautifully demonstrated, will mainly by due to the circumstance that in their case the cohesion limits cannot be exceeded by tension. (Compare B. Kirsch „Über den Flüssigkeitsgrad fester Körper", Zeitschr. d. österr. Ingen.- u. Architektenvereins, 1896 No. 11). As regards "scratching methods" for plastic materials the relation between scratch-hardners and mean specific resistance to shearing has been elucidated by the remarkable work of Haußner on planing metals; Haußner proved that the scratch-hardness depends equally upon the compression limit and the resistance to shearing. (Comp. A. Haußner, "Hobeln und Härte", Österr. Zschr. für Berg- u. Hüttenwesen, 1892, pp. 379 and 397.)

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

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II 2

SIMPLIFIED BALL-HARDNESS TESTING MACHINE AND RESULTS OBTAINED THEREWITH.*)

By **A. Martens** and **E. Heyn**, Gr.-Lichterfelde W.

Translated from the German by Dr. H. Borns, London.

Communication from the Royal Materialprüfungsamt at Gross-Lichterfelde near Berlin.)

In determining the hardness number after Brinell a steel ball of a certain diameter D is forced under a certain pressure P into the respective material. The diameter d of the impression produced is measured by the aid of the microscope or of a special measuring device. The depth of the cavity is then calculated from the formula

$$h = \frac{D}{2} - \sqrt{\frac{D^2}{4} - \frac{d^2}{4}},$$

and the hardness number H is stated as ratio of pressure P to the area of the spherical surface $\pi D h$, such that

$$H = \frac{P}{\pi D h} \quad \ldots \ldots \ldots \quad (1).$$

The deduction of h from the measured diameter of the impression according to the formula

$$h = \frac{D}{2} - \sqrt{\frac{D^2}{4} - \frac{d^2}{4}}$$

is based upon the hypothesis, that the radius of curvature R of the spherical impression be equal to the radius $\frac{D}{2}$ of the unloaded

*) Extract from memoir published in the "Mitteilungen über Forschungsarbeiten des Vereines deutscher Ingenieure".

ball. This hypothesis is not justified however. For owing to the elastic flattening of the ball, R will in general be greater than $\frac{D}{2}$.

It results that the calculated value of the area of the spherical calotte has nothing to do with the real area surface of the impression, and that the value derived from formula (1) which refers to the pressure enacted upon unit area of this calculated calotte, has no physical significance.

The idea suggested itself hence to avoid the elaborate calculation of h from the measured value of d and to measure h, the depth of the cavity, directly. The Martens hardness-tester described in the following lines, has been designed for this purpose. The observation of h does not require the use of a microscope; h is read off from the height of a mercury column in a capillary.

In a recent publication E. Meyer[1]) defines the ball-test hardness p_m as the mean pressure upon the unit area of the impression circle, i. e., upon the unit area of the projection of the calotte

$$p_m = \frac{P}{\frac{\pi}{4} d^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2).$$

This definition enables us to dispense with the calculation of the surface of the calotte. The method yet labours under the difficulty of determining the diameter d. E. Meyer rightly emphasises that one single value of p_m for a particular pressure P should not be selected for determining the hardness, but that we should represent the relation between p_m and P by a curve, each point of which would equally be entitled to serve as hardness measure. His own investigations led him to the relation

$$P = a\, d^n \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

in which a and n are constants for a given material in a definite original condition.[2])

The plotting of the whole curve of Meyer can be dispensed with when we make use of the device of Martens, because the relation between P and the depth of the cavity h is very simple for the beginning of the penetration, that is, for small values of P;

[1]) "Untersuchungen über Härteprüfung und Härte", Zeitschrift des Vereines deutscher Ingenieure, 1908, pag. 645.

[2]) Rasch had previously arrived at a similar relation.

n this case the curve is rectilinear so that it is indeed possible o deduce the hardness from the straight-line portion of the curve. [he hardness number is therefore determined for very small values ɔf P. This is an important feature, since we wish to know the ıardness so far as possible for the original condition of the material, ınd not for the artificial state into which it has been converted ɔy the deep penetration of the ball (by being worked in the cold).

The determination of the depth of penetration h by means ɔf the Martens device can always be accomplished in a very ;imple manner. A special advantage is that the pressure of any vater supply main will be sufficient for conducting the test.

A. Description of the Hardness Tester (type Martens).[1])

The machine, which Louis Schopper of Leipzig supplies n excellent execution, is illustrated in Fig. 1.

The machine comprises a ıydraulic press, in the lower ɔortion, and the appliances for neasuring the depth of penetration h, in the upper portion.

The pressure device is illu;trated in section in Fig. 2.

The water is taken from he main and enters through he connection a under the eather diaphragm b, over which ı rubber diaphragm c is placed; ɔoth these discs are held water;ight between the base e and he cover-plate d of the press. Nhen the water is admitted, he diaphragms b and c are

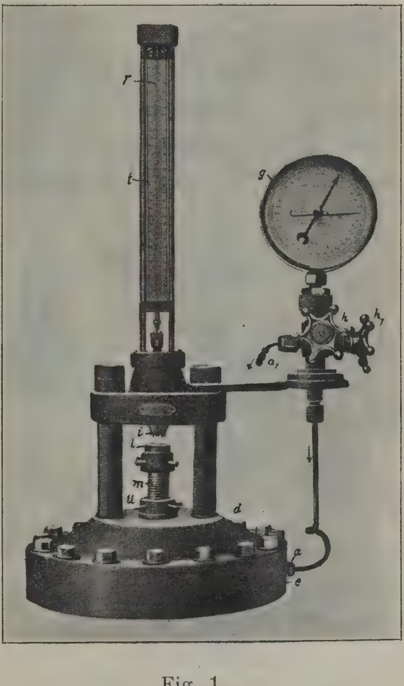

Fig. 1.

Hardness Tester (type Martens).

[1]) Martens first indicated the eading features of the design in Sitzungsberichte der kgl. Akademie ler Wissenschaften", Berlin 1905, ɔag. 1035, and later in the "Verhandungen des Vereines zur Beförderung les Gewerbefleißes", March 5, 1906.

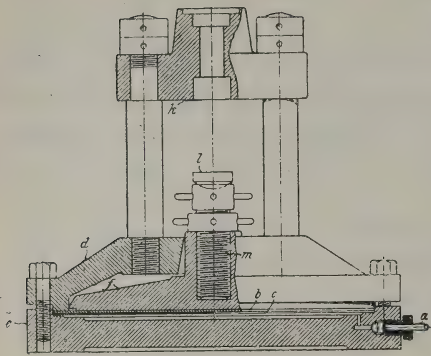

Fig. 2.

Press for the Brinell test.

raised and the plunger f, whose effective area amounts to 500 cm² (about 77 sq. in.) is put under a definite pressure P. This pressure is read off on the gauge g (fig. 1), which is divided into 300 degrees of 5 kg/cm². When, therefore, the gauge marks z degrees, the pressure will be

$$P = z \cdot \frac{25}{3} \text{ kg} \quad . \quad . \quad (4).$$

The admission of the water and the pressure P are regulated by the valve h. Since the gauge reads up to $z = 300$, the maximum admissible pressure is 2500 kg. The steel ball of 5 mm diameter is attached to the head i by means of a little wax; i bears against the yoke k, see fig. 3 and 4.

The specimen to be tested is placed upon the table l, which rests in a ball bearing on the upper part of the main adjustment screw m. By means of m the distance between the upper edge of the table l and the ball n is adjusted to the thickness of the specimen.

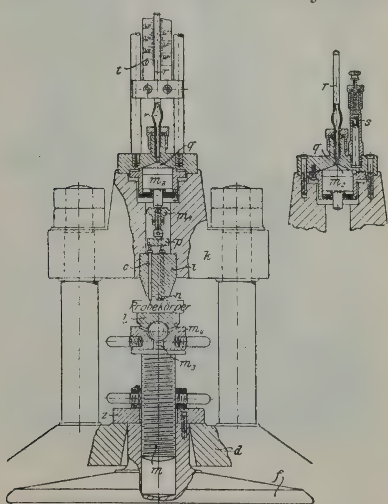

Fig. 3 and 4.

When the hydraulic pressure P is to be diminished, the valve h is closed and the water cut off, while the hand wheel h_1 establishes communication between the space under the plunger f and the water discharge pipe a_1. For reasons presently to be explained it is advisable to attach the pressure regulating devices $h\, h_1\, a_1$, not as indicated in fig. 1 to the upper side of the yoke, but rather below to the table on which the machine stands, and to give the discharge pipe a_1 a slight fall.

The appliances for measuring the depth of the penetration will be understood from fig. 1, 3. 4. The little steel rods o settle on the surface of the specimen; they support on points the steel plate p. On this plate rests a piston m_1, and on this again, in the centre of gravity of the three points support of p the steel piston m_2, which is ground mercury-tight into its cylinder. Mercury fills the space q above the piston m_2 and part of the capillary r. By the aid of the small adjustment piston s (fig. 4) the mercury in r is brought back to zero. When now the pressure P forces the ball n into the specimen, the steel rods o and together with it the parts $p\, m_1\, m_2$ will be lifted. Mercury is forced out of q and rises in the capillary r by an amount which is read off on the scale t; this amount corresponds to the depth h to which the ball has penetrated.

The calibration of r is effected with the aid of a micrometer screw, which is supplied with the apparatus and is placed on the main adjustement screw m instead of the table l. This screw fits into the threaded nut m_3 and is provided with an indexed head, while the part m_4 of m bears the zero mark. The head of the micrometer screw is moved up together with the main screw m, until it begins to lift the rods o of the depth indicator. The mercury in its capillary r is adjusted to zero by means of the piston s. By turning the head of the micrometer screw the little rods o are then raised by definite amounts, and the corresponding heights of the mercury in r are read off. Afterwards the micrometer screw is turned in the opposite direction, and the readings are repeated while the mercury level is lowered.

The weight of the mercury column on the depth indicator throws a pressure on the test specimen which counteracts the pressure P. With the maximum penetration depth h this counterpressure does not amount to more than 3 kg, however, and it is considerably smaller with smaller values of h; this factor may hence be disregarded.

The elastic deformations resulting in the depth indicator under the observed pressure due, e. g. to elastic compression of the rods o or to elastic strains of the point-bearing of the steel plate p, cannot affect the determination of the depth h, since they were already taken into account when the scale t was calibrated by means of the micrometer screw.

B. Resultats obtained with the Hardness-Tester (type Martens) and their Interpretation.

When the specimen is put under a ball-pressure P, the mercury in the depth indicator will rise by h' mm. This rise h' is, however, not immediately equal to the permanent depth of penetration h of the ball; the value h' comprises, in adtition to h, the amount h_ε due to elastic deformations in the apparatus and to elastic compression of the ball. The elastic depression of the specimen itself may further have to be considered.

When the ball is forced into a substance under increasing pressure, the relation between the pressure P and the position of the depth indicator is represented by the curve OA in Fig. 5, in

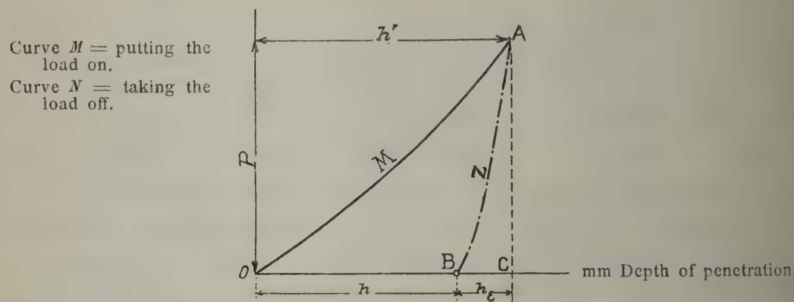

Fig. 5.

which the pressures are the ordinates and the positions of the depth indicator the abscissae. At the point A the position of the depth indicator h' corresponds to the pressure P. If we now close the water admission valve and gradually open the discharge valve, the pressure will diminish in the gauge, and the mercury of the depth indicator will go down at the same time. But the curve AB (taking the load off) will be different from OA (putting the load on). In releasing the load the mercury will descend slowly and will, at pressure zero, remain for some time at the level h corresponding to the point B; later, when the outlet is fully opened, the mercury level will quite go down to zero. The length $OB = h$ will correspond to the actual permanent depth of penetration of the ball. The length $BC = h_\varepsilon$ will correspond to the elastic deformations of the device, of the ball, and of the specimen itself.

In order that the indicator will temporarily stop at B, when P is taken off, the outlet of the discharge pipe is advantageously placed at a slightly lower level than the leather diaphragm of the press. The control of the point B may also be effected in the following manner. The specimen is lowered, by the aid of the adjustment screw m, until it is quite out of contact with the ball; m is then raised again, until contact is just established once more. The level of the mercury will then again be h.

It will be understood that the ordinary manipulation of the machine does not require the determination of the elastic deformations h_ε, which are eliminated.

The device admits, however, of determining these alterations. We will only point out on this occasion that the ball may elastically be flattened to a considerable extent; the flattening may indeed amount to 80 per cent and more of the value of the permanent penetration h. This flattening is comparatively greater with smaller pressures than with higher pressures, and greater with hard than with soft test-materials.

The question is, in which way the depth of penetration h indicated by the Martens hardness-tester, characterises the hardness of the material.

We might, in accordance with Brinell, express the hardness by the quotient $\frac{P}{2\pi r h}$, in which r is the radius of the ball when not under load. But this product $2\pi r h$ does not correspond to the surface of the impression calotte, which is $2\pi R h$, in which R is the radius of curvature of the impression and variable with P. In the quotient $\frac{P}{2\pi r h}$ we have hence r as arbitrary constant. It appears simpler, therefore, to base the hardness scale directly on the ratio of pressure P to depth of penetration h. As this ratio will vary with the radius of the ball, it is suitable always to use a ball of a certain diameter, viz. 5 mm. If greater balls were to be applied, we should sacrifice the advantage of this machine, that it can take its hydraulic water from any water main.

When we plot the pressure P for different materials as ordinates against the abscissae of the penetration depth h, we obtain curves as in the diagram Fig. 6.

The productions of the curves pass through the origin. For low pressures the curve approaches a straight line G; for higher pressures the curve deviates from the straight line, mostly upward, more rarely downward.

It is not necessary hence to characterise the hardness by the entire function $P = f(h)$. It will suffice to determine the pressure P for some very small penetration h_n, which is smaller than OD in fig. 6, and for which therefore $P = f(h)$ may with sufficient accuracy be regarded as a straight line. For the hardness-tester described and for the 5 mm ball the suitable value of h_n has been found to be $h_n = 0{,}05$ mm. The hardness scale is hence designated by the pressure $P\,0{,}05$ required to force a ball of 5 mm diameter to a depth of 0,05 mm into the material.

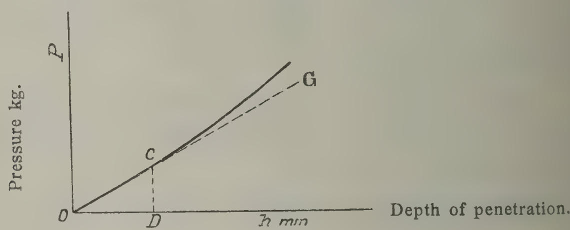

Fig. 6.

The complete memoir publishes details of a series of tests with different materials, and attention is drawn to the strong after effects (set phenomena) observed in some materials (tin, magnesium, white metal). If we work with small penetration depth h, however, such as the 0,05 mm proposed, the after-effect will no longer be measurable a few minutes after the application of the pressure; the effect will only become appreciable with higher pressures.

The memoir also refers to tests conducted with copper in order to investigate the influence of thermal treatment upon the result of the hardness-tests.

When we group the materials examined in the order of their increasing ball hardness $P\,0{,}05$, we come to the following series:

Number	Metal and its Condition	Ball-hardness $P_{0,05}$ kg	Remarks on Composition
1	Tin	14	
2	White metal for bearings, cooled slowly	21	Sn 83,1; Sb 11,1; Cu 5,4
3	Aluminium	25	
4	Magnesium	26	
5	White metal, cooled rapidly	26	as 2
6	Antimony	27	
7	Fire-box copper, annealed at 900°	30	
8	„ „ „ „ „ 500°	43	
9	Brass cast (F 70)	61	Cu 60,4; Zn 27,1; Sn 1,2; Pb 1,1; Fe 1,1
10	Copper as taken from the fire-box	81	copper as in 7 and 8
11	Bronze for bearings cast in sand[1]	83	Cu 83,6; Sn 16,0; Zn 0,2; Pb 0,07; As 0,2
12	Mild steel, low carbon, S 660	96	C 0,07; Si 0,06; Mn 0,10; P 0,010; S 0,019; Cu 0,015
13	Bronze for bearings, chilled[1]	136	the same alloy as 11
14	Tool steel, S 722, forged	277	C 1,03; Si 0,26; Mn 0,19; P 0,02; S 0,03
15	Tool steel S 774 quenched in water at 900° C, and then tempered at 600 to 700 °C	260 to 277	C 0,95; Si 0,35; Mn 0,17; P 0,012; S 0,024
16	„ 500 °C	446	„
17	„ 400 °C	595	„
18	„ 275 °C	1060	„
19	„ 200 °C	2285	„
20	„ 100 °C	2775	„
21	„ not tempered	2775	„

[1]) The ball impression deviated so much from circles that measurement of the diameters appeared impossible; the h could easely be determined with the hardness-tester, however.

We should finally explain the physical significance of the circumstance that the curve $P = f(h)$ approaches a straight line G for low pressures, and that this line G passes through the origin and is determined by the equation $P = C\,h$, where C is constant. If p is the mean pressure on the plane of the impression circle $\frac{\pi}{4} d^2$, then

$$P = p\,\frac{\pi}{4} d^2 \quad \dots \dots \quad (5),$$

in which p and therefore also d are variable. If we designate by R as before the radius of curvature of the impression calotte (not the radius of the unloaded ball),

we have $$\frac{d^2}{4} = h\,(2\,R - h)$$

and consequently $$P = \pi\, p\, h\,(2\,R - h) \quad \ldots \ldots \ldots \quad (6).$$

For very small pressures P and consequently very small depths of penetration h, the h may be neglected by comparison with $2\,R$ in the factor $(2\,R - h)$, so that approximately P equals

$$2\,\pi\, p\, h\, R \quad \ldots \ldots \ldots \quad (7).$$

The experiments demonstrate that below certain limiting values of P and h the equation $P = C\,h$ may be regarded as approximately correct. We may hence, within the limits indicated, assume

$$p\,R = \text{constant} \quad \ldots \ldots \ldots \quad (8).$$

That is to say, the radius of curvature R must rapidly decrease with increasing pressure. This constancy of $p\,R$ is valid only for small penetration depths; but it is valid just for those depths h, for which both p and R vary most strongly. (Further particulars will be found in the memoir.) Thus there holds for the mean areal pressure p and the radius of curvature of the calotte (equal to the radius of curvature of the flattened ball) a relation similar to that which exists between pressure and volume of a gas according to the law of Mariotte-Boyle.

II3

THE CONE-PRESSURE TEST FOR DETERMINING THE HARDNESS OF PERMANENT WAY MATERIALS.

By Dr. techn. **August Geßner,** Vienna.
Translated from the German by Dr. H. Borns, London.

Permanent-way materials have beente sted by Ludwik's cone-ressure method with two objects: to inquire into the suitability f the method for practical purposes and to ascertain the relation etween the cone-pressure hardness and the tensile strength.

The experiments have been conducted in connection with ıe acceptance tests of the materials supplied to the J. R. Austrian tate Railways during the year 1908, in the Trzynietz Iron Works f the Österr. Berg- und Hüttenwerks-Gesellschaft with the aid of a Amsler-Laffon cone-pressure hardness tester[1]) on a Mohr & ederhaff testing machine.

The very extensive material experimented upon comprised: ails, railway sleepers, bed-plates, fish-plates and steel rossings.

The specimens were not prepared in any way apart from eing cleaned; an exception was made in the case of the steel oints in which the outer skin containing coarse impurities had ompletely to be removed.

A full account of the research is about to appear.

The following are the chief results:

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[1]) Compare P. Ludwik, „Die Kegelprobe, ein neues Verfahren zur Härte-stimmung von Materialien". Berlin 1908, Julius Springer.

The ratio of tensile strength to cone-pressure hardness had a mean value of about 0,335, the range of deviation being $\pm$ 6 per cent. The carbon percentage did not exercise any pronounced influence.

The lowest tensile strength of 65 kg/mm^2 (42 tons per sq inch), admissible for rails, corresponded to a cone-pressure hardness of about 190.

The tensile strengths of sleepers and of smaller parts for the permanent way varied between 39 and 47 kg/mm^2 (24,75 and 29,8 tons per sq. inch) and the corresponding hardness numbers between 117 and 144. The range of variation is hence approximately the same for the tensile strengths as for the hardness numbers.

It should be emphasised that the cone-pressure apparatus proved most satisfactory, and that all the experiments were made with the same plunger.

The results thus justify the expectation that it will in many cases be possible and avantageous, to replace the elaborate and expensive tensile strength tests by the much simpler and cheaper cone-pressure hardness tests.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

III 2

ON NOTCHED-BAR IMPACT BENDING TESTS.

By Prof. **F. Schüle**, in conjunction with **Ed. Brunner**, of Zürich.

Translated from the German by Dr. H. Borns, London.

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1. The Direct-Fall Machine.

The direct-fall machine is the simplest apparatus for impact bending tests. It occupies little space, the specimens can securely be mounted, and the height of fall of the tup can be adjusted at will. That preference is on the whole given to the pendulum hammer is due to the fact, that the work done in fracture can directly be deduced from the vertical height, through which the hammer has fallen. In direct-fall machines Frémont first determined the work done by measuring the compression of a helical spring which the tup struck after breaking the specimen. This method is not accurate; the impact causes the spring to oscillate, and the oscillations are propagated in the vertical, so that the compression can not sharply be measured. The work done might also be deduced from the compression of crushers. Amsler has constructed a device which graphically indicates the velocity of fall immediately before and after the fracture of the test piece; the work done in falling is deduced. This method has answered best.

The arrangement of the machine will be understood from Fig. 1, which illustrates the machine supplied by Amsler in 1904 for the Federal Testing Laboratory at Zurich (Eidgenössisches Materialprüfungsamt). The machine rests on a cast-iron plate of 100 by

90 cm (39 by 35 in.); the standards are two railway rails, and the adjustable height of fall can be increased up to 4 m (13 ft.). The height is directly read off, for any level of the specimen, from an adjustable tape which is divided into centimeters. The tup can be removed after taking out a moveable piece in the lateral guides; the weights of the tup are 5, 10, 20, 50 or 100 kg (11 to 212 lbs.). The machine can also be used for impact breaking tests; this communication confines itself to impact bending tests.

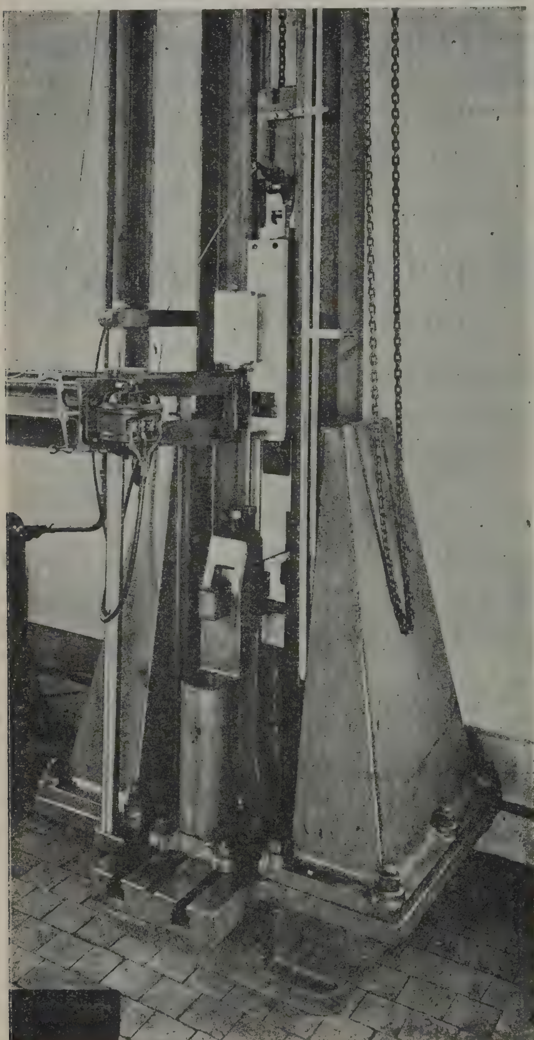


Fig. 1.

The diagram is drawn by a style, fixed to the tup, on the card covering a revolving drum. This drum is adjustable both in the vertical and in the horizontal, and the style can thus be arranged to be half-way up the card at the moment the blow is struck. The maximum height of fall is 4 m. The cylinder describes 1400 revolutions, being turned by $^1/_{16}$ horse-power electric motor.

If ABC be the diagram, of which AB is drawn before the fracture of the test bar, and $BB'C$ during and after the fracture,

the tangents of the angles β and β_1 will be proportional to the velocities. If further h be the height before fracture at B, h' the reduced height after fracture, and P the weight of the tup, then the work done

$$A = Ph\left(1 - \frac{tan^2\beta_1}{tan^2\beta}\right).$$

The test-bars of the Federal Testing Laboratory have a length of 16 cm (6·3 in.), a height of 2 cm (0·8 in.), and the width of the respective plate thickness; the clamped lenght is 12 cm (4·72 in.). The notch has a depth of 5 cm (1·97 in.) and is rounded off to a semi-circle of 4 mm diameter. If c be the width of the rod, d the thickness or height at the notch (1·5 cm, 0·59 in.), then the specific work done in fracture $A = \frac{A}{c\,d}$ in kg/cm².

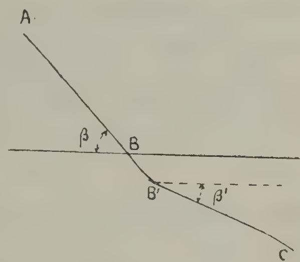


Fig. 2.

The machine admits of applying blows varying, with the different tups, from 1 to 400 kgm (7 to 2890 ft. lbs.). The pendulum hammers most largely used in Germany, those of the Charpy system, consist of three types with maximum energies of 250, 75, 10 kgm (1810, 540, 72 ft. lbs.) respectively. Instead of the floor space of 0·9 by 1 m, those machines require floor spaces of 5·0 by 1·7 m, 4·25 by 1·55 m, and 0·85 by 0·5 m.

2. Interpretation of the Experimental data.

It is customary to divide the work done in fracture by the sectional area of the test-bar at the notch, and to enter the resulting figure as specific work done in fracture per cm². This procedure can not scientifically be justified, however, and has probably been adopted simply because the phenomena of notched-bar impact tests are so complex, that a rational analysis of the results did not so far appear possible.

The work done is consumed partly by the elastic deformation, partly by the permanent deformation (or set) and by the fracture of the test-bar. The former component can not subsequently be determined. The latter will have strained, beyond the yield point, a certain volume of the material in the neighbourhood of the notch. When the sides of the test-bar are polished, which is more frequently done now as it facilitates the general observations, the test will

spoil the polish of the whole volume, so far as strained beyond the yield point. In the Federal Testing Laboratory comparative notched-bar impact tests have been made on bars of 2 cm (8 in.) height, 1·5 cm (0·59 in.) width, all taken from the same rod of mild steel, with the object of determining this volume of strained material, and with the further object of studying the influences of two different notches, half round, 4 mm in diameter, and sharp cuts at angles of 45⁰. In every case two bars were notched in the same way.

In addition to the usual determination of the work done in fracture, in kg per cm^2 of sectional area at the notch, the work done has been deduced in kgm/cm^3 of material strained beyond the yield point. The following Table I sums up the results of the tests made with round notches.

Table I. Round Notches.

Number of test-bar:	1	2	3	4	5	6	7	
Depth of notch	0·4	0·5	0·59	0·69	0·80	0·9	0·98	cm
Sectional area at notch .	2·40	2·25	2·11	1·96	1·80	1·65	1·53	cm^2
Work done in fracture per unit area	32·0	28·1	13·0	20·6	20·1	19·4	11·2	kgm/cm^2
	33·3	26·1	26·9	24·0	18·4	14·6	14·1	kgm/cm^2
Volume of material strained beyond the yield point .	10·02	7·98	5·02	4·50	4·06	3·57	2·98	cm^3
	9·96	7·68	6·87	4·89	4·32	3·60	2·92	cm^3
Work done in fracture per unit volume	7·65	7·96	5·46	8·95	8·94	8·99	5·76	kgm/cm^3
	7·95	7·64	8·34	9·61	7·66	6·69	7·38	kgm/cm^3

The outlines of the parts strained beyond the yield point for the bars of one series are marked in Fig. 3. In the case of the bars with notches of 4 or 5 mm (0·16 or 0·2 in.) depths the strained volume occupies the whole height of the bar; when the notch depth ranges from 6 to 10 mm (0·24 to 0·39 in.), the lower portion of the bar remains unstrained.

Table I shows that, with increasing notch depth, the work done in fracture decreases considerably when referred to the sectional area of fracture, but remains almost constant when referred to the volume strained beyond the yield point. Certain irregularities may be ascribed to differences in the materials of the various bars.

The influence of the depth of the notch was similarly investigated for the sharp-angled notches of 45⁰, the material being the same mild steel. The lateral faces of the bars were again polished for the purpose stated, and two similar bars were always tested. The results are reproduced in the following Table II.

Table II. Sharp-Angled Notches.

Number of test-bar:	10	11	12	13	
Depth of notch	0·2	0·4	0·6	0·8	cm
Sectional area at notch	2·70	2·40	2·10	1·80	cm^2
Work done in fracture per unit area	3·88	1·30	1·19	1·30	kgm/cm^2
	5·54	2·83	1·35	1·12	kgm/cm^2
Volume of material strained beyond the yield point	5·04	1·50	1·19	1·16	cm^3
	5·40	2·97	1·19	1·20	cm^3
Work done in fracture per unit volume	2·08	2·08	2·10	2·02	kgm/cm^3
	2·76	2·28	2·39	1·68	kgm/cm^3

Fig. 3 shows the outlines of the volumes which were strained beyond the yield point, the volumes being measured with a planimeter. Again the values of the work done in fracture differ very strongly, when referred to the cm^2 of sectional area at the notch. When the y are referred to the cm^3 of the volume strained beyond the

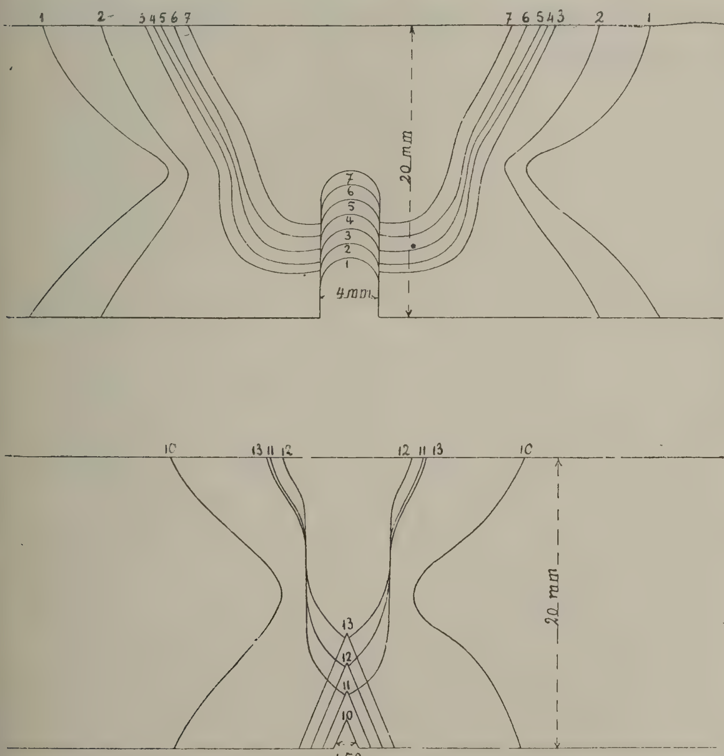


Fig. 3.

yield point, the values become much more concordant, and indeed constant for the one series of test-bars. The other series shows irregularities which may be due to the material.

The resulting mean work done in fracture per unit volume of material strained beyond the yield point is:

for semicircular notches . . 7·78 kgm/cm³
for sharp-angled notches . . 2·17 „

The ratio of these two figures is 3,6, indicating a remarkable influence of the shape of the notch.

Conclusion:

By determining the volume which is strained beyond the yield point in a test-bar which is polished on both sides, and by calculating the work done in fracture per unit of this volume, the influence of the depth of the notch can be eliminated, and the influence of the shape of the notch on the strength of the material can be determined.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

V1

REPORT IN CONNECTION WITH THE TABLES OF RESULTS OF EXPERIMENTS ON THE STRENGTH-PROPERTIES OF CAST-IRON OF VARIOUS SECTIONS TAKEN FROM SEPARATELY-CAST SAMPLES AND FROM SAMPLES CUT OUT OF CASTINGS.

By **Brothers Sulzer,** Winterthur, Switzerland.

Translated by A. R. Liddell, Charlottenburg.

Experience shows that separately-cast test-samples give higher values for bending and tensile strength than such as are cut out of castings. Our object in making the two series of tests was to ascertain, what influence the slow cooling, to which castings may be subjected, exercises on the grain or on the strength of the cast-iron, and what part is played therein by the different thicknesses of metal.

It is a well-known fact that, with given thickness of metal, cast-iron shows itself softer, i. e. more coarsely-grained, when it forms a core-piece, and harder, i. e. more finely-grained, when it is cast in the form of a flat piece or as a bar. The difference in the grain is, of course, the greater, the thinner the wall of the section.

Series I of the tests was made by us on a cast-iron of tough quality, such as we use for high-pressure pieces for steam-pipes and other structural parts on which strength requirements of a high order are made, while Series II concerns ordinary engineers' cast-iron for larger parts. The separately cast test samples and the castings from which test-pices were worked, were taken from one

and the same ladle. All the moulds were blackened and well dried. The rectangular test-pieces were cast in an inclined position, those of rounded section and the larger castings vertically, in each case from below. We allowed the bars, plates, and hollow castings to cool completely in the moulds.

The rectangular tensile-test pieces were worked directly out of the castings, while the rounded tensile-test pieces, the bars for the impact tests, and the cubes for the compressive tests were worked out of the broken bend-test samples. All the results given are means of tests made with at least three samples in each case. The impact strength in kgs. per metre is that corresponding with the sum of the work done by a number of single blows of a rammer of 12 kgs. in weight with a distance apart of the supporting knife-edges of 160 mm. The first blow was delivered from a height of 150, 300, or 400 mm. according to the strength of the sample. After each blow the height of fall was increased by an additional 100 mm., and the blow which finally produced the fracture has in each case been included in the number reckoned.

While the separately-cast test-samples with rectangular and circular sections, and the samples taken from plates of successively reduced section in general show gradually increasing strength values, the samples worked out of hollow castings of all the different sizes experimented with give values that are pretty much the same. The test-samples of circular section show greater bending and tensile strengths than those of rectangular section. The samples worked out of plates are, in strength, somewhat behind those separately cast. Similarly the strength figures for the various thicknesses of metal of the hollow castings fall short of those of the separately cast samples, and, in a less degree, of those of the plates. This is less apparent in connection with castings of the larger dimensions, but shows itself very clearly in those of the smaller ones. The comparison of the impact strengths show that these are greater in the samples worked out of larger bodies than in the ones that were separately cast, and in like manner the flexure of the former samples was greater than that of the latter.

The plates cooled somewhat more slowly than the bar-samples. The material proved somewhat softer, and accordingly gave somewhat smaller values for the bending, tensile, and compressive strengths, but was better as regards flexure and strength to resist impact.

We see this in more pronounced form in connection with the hollow castings. These have naturally cooled more slowly than the plates, and indeed the heat must have been distributed over the whole casting in such a manner, that the cooling took place in all the dimensions of 30, 40, 50, and 60 mm simultaneously. The grain, and with it the strength of the material, remained the same in all the four walls.

and from Test Samples worked out of Castings.

Test Samples worked out of Castings												
of Moulding Sand					Mould of Sand. Core of Clay							
Flexure	Tensile Strength		Compressive Strength. Compression in %	Impact Strength	Number of Sample	Dimensions of Sample	Gauge Length	Bending-Strength	Flexure	Tensile Strength		Compressive Strength. Com-[cut off]
mm	mm in Dia.	kg per mm²	kg per mm²	kg/m	No.	mm	mm	kg per mm²	mm	mm in Dia.	kg per mm²	kg p[cut off] mm
					L							
18·8	60/45	18·0			I–III	60×60	1000	32·1	19·3	60/45	17·7	
5·4	40	19·7			A		500	34·2	5·7	40	19·0	
22·4	50/45	18·2			IV–VI	50×50	1000	32·1	20·8	50/45	18·0	
6·2	40	19·2			A		500	34·4	6·3	40	19·3	
28·4	40/50	18·0	72·1	36·0	VII–IX	40×40	1000	33·2	27·1	40/50	19 0	70·[cut off]
7·4	30	19·2	15·0%		A		500	33·9	7·7	30	19·2	15 2[cut off]
32·0	30/40	18·8	72·8		X–XII	30×30	1000	32·4	33·5	30/40	18·8	71·[cut off]
11·0	25	19·3	17·7%		A		500	33·0	12	25	19·5	17·9%

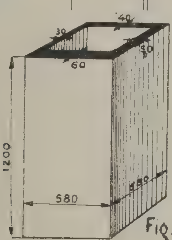


Fig. 3.


Fig. 1.

Table I.

Strength Properties of Cast-Iron of Tough Quality from Different Sections of Separate Castings and from Test Samples worked out of Castings.

Separately-Cast Test Samples — Circular Section

Number of Sample	Dimensions of Sample	Gauge Length	Bending-Strength	Flexure	Tensile Strength		Compressive Strength, Compression in %	Impact Strength
No.	mm	mm	kg per mm²	mm	mm in Dia.	kg per mm²	kg per mm²	kg/m
	◯							
I–III	60	1200	44·9	29·2	40	23·8		
IV–VI	50	1000	44·3	22·8	40	24·2		
VII–IX	40	800	44·2	19·3	34	24·1	94·0	
							15·0%	
X–XII	30	600	45·4	18·3	20	25·5	96·6	
							18·3%	
XIII–XV	20	400	55·8	9·0	14	35·3		
XVI–XVIII	10	250	57·3	5·0				

Separately-Cast Test Samples — Rectangular Section

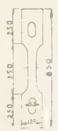
Number of Sample	Dimensions of Sample	Gauge Length	Bending-Strength	Flexure	Tensile Strength		Compressive Strength, Compression in %	Impact Strength
No.	mm	mm	kg per mm²	mm	mm in Dia.	kg per mm²	kg per mm²	kg m
	▨							
I–III	60×60	1000	33·0	16·3	40	18·1		
A		500	33·1	4·4				
IV–VI	50×50	1000	35·0	17·3	38	19·4		
A		500	35·2	4·5				
VII–IX	40×40	1000	37·0	19·2	28	23·2	82·0	31·2
A		500	37·1	5·7			14·1%	
X–XII	30×30	1000	42·5	27·0	18	25·6	77·9	
A		500	42·4	8·5	25	25·6	15·7%	

Test Samples worked out of Castings — Mould and Core of Moulding Sand

Number of Sample	Dimensions of Sample	Gauge Length	Bending-Strength	Flexure	Tensile Strength		Compressive Strength, Compression in %	Impact Strength
No.	mm	mm	kg per mm²	mm	mm in Dia.	kg per mm²	kg per mm²	kg m
S	▨							
I–III	60×60	1000	32·3	18·8	60/45	18·0		
A		500	33·9	5·4	40	19·7		
IV–VI	50×50	1000	33·1	22·4	50/45	18·2		
A		500	34·5	6·2	40	19·2		
VII–IX	40×40	1000	33·0	28·4	40/50	18·0	72·1	36·0
A		500	33·4	7·4	30	19·2	15·0%	
X–XII	30×30	1000	33·1	32·0	30/40	18·8	72·8	
A		500	33·8	11·0	25	19·3	17·7%	

Test Samples worked out of Castings — Mould of Sand, Core of Clay

Number of Sample	Dimensions of Sample	Gauge Length	Bending-Strength	Flexure	Tensile Strength		Compressive Strength, Compression in %	Impact Strength
No.	mm	mm	kg per mm²	mm	mm in Dia.	kg per mm²	kg per mm²	kg m
L	□							
I–III	60×60	1000	32·1	19·3	60/45	17·7		
A		500	34·2	5·7	40	19·0		
IV–VI	50×50	1000	32·1	20·8	50/45	18·0		
A		500	34·4	6·3	40	19·3		
VII–IX	40×40	1000	33·2	27·1	40/50	19·0	70·5	36·6
A		500	33·9	7·7	30	19·2	15·2%	
X–XII	30×30	1000	32·4	33·5	30/40	18·8	71·2	
A		500	33·0	12	25	19·5	17·9%	



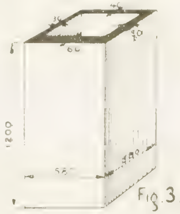


Fig. 1

Fig. 3.

Material			Chemical Analysis						Crude Drawn Metal									Annealed Metal							
Nature	No.	Diameter of the bar	*Cu*	*Zn*	*Sn*	*Pb*	*Fe*	Other Elements	Tension Test		Hardness Test			Shear Test		Impact Test		Tension Test		Hardness Test			Shear Test		Impact Test
									R	$A\%$	Δ	$C=\frac{R}{\Delta}$	$R=0{,}405\,\Delta$	C	$R'=\frac{C-2\,3}{0{,}3}$	Mesnager	Frémont	R	$A\%$	Δ	$C=\frac{R}{\Delta}$	$R=0{,}550\,\Delta$	C	$R=5\,(c-6)$	Mesnager
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Copper	129	20	99·98						32·8	8·2	77	0·427	31·2			10 (*n. c.*)		19·4	29	38·5	0·504	21·1			13·5 (*n. c.*)
	627	30	99·52		0·042	0·017	*Sb*=0·031	*As*=0·40	32·2	9	76	0·423	30·8	11·35	30·2	7·5		21·5		39·5	0·545		10·2	21	11·5 (*n. c.*)
Brass	167	30	58·35	39·49	0·37	1·27	0·61	„	47·5	27	109	0·435	44·1	15·4	43·5	„	5·5	43·4	35			47·8	14·8	44	„
	166	40	59·25	37·93	0·32	1·57	0·60	„	44·5	25	98	0·448	39·6	15·6	44·1	„	5	41·3	40	71	0·578	39	13·6	38	„
	173	20	59·47	37·19	0·53	2·17	0·66	„	51·8	22	119	0·427	48·2	17·9	52	„	4	42·4	45·5	78	0·543	42·8	14·2	41	„
	87	10	59·86	37·30	0·26	1·52	0·73	„	50·7	18				17·3	50	„	„	39·8	40				16·2		„
	133	20	60·00	39·66	0·10	0·12	0·73	„	42·6	25·8	114	0·372	46			8	„	31·1	41	57·5	0·541	31·6			13
	172	40	60·05	37·08	0·22	2·20	0·66	„	45·5	36	98	0·464	39·6	14·8	41·6	„	4·5	41·4	42	79	0·522	43·4	13·9	39·5	„
	357	20	60·21	37·51	0·18	1·42	0·52	„	44·1	21·5	„			16·1	45·8	„		36·7	45				14·2	41	„
	359	20	60·31	38·30	0·24	0·92	0·19	„	42·1	27·5	„			16·	45·4	„	„	37·4	45				13·6	38	„
	170	40	60·86	37·33	0·12	1·29	0·18	„	40·6	44	„			14·8	48·6	„	5	37·7	49				13·6	38	„
	354	20	60·97	38·42	0·12	0·23	0·19	„	42·7	25	„			16·6	47·3	„	„	36·7	49·5				13·5	37·5	„
	358	20	61·54	36 17	0·47	1·32	0·47	„	44·1	21	„			15·4	43·5	„	„	30·9	48				13	35	„
	134	20	61·65	37·59	0·49	0·10	0·21	„	40·2	35·1	92	0·438	37·4			5	„	32·4	58·9	57	0·569	31·3			7
	165	40	61·69	37·93	0·93	1·57	0·69	„	37·3	7	85	0·439	34·4	15·1	42·5	„	4	30·6	17	65	0·472	35·7	12·9	34·5	„
	168	20	62·62	35·32	0·69	0·92	0·74	„	49·7	13	117	0·424	47·3	16·8	48·3	„	3·5	39·9	40	78	0·512	42·8	14·2	41	„
	135	20	64·40	34·83	0·38	0·34	„	„	35·5	41·7	90	0·394	36·5			11	„	27	61.7	43	0·628	23·6			14·5
	171	20	65·40	31·92	0·30	1·71	0·52	„	47·5	16	108	0·439	43·7	16	45·4	„	4·5	38·1	49·5	74	0·513	40·7	12·8	34	„
	356	20	65·50	32·26	0·55	1·18	0·20	„	35·4	30				14·4	40	11·5	„	28·7	63				12	30	„
	136	20	66·76	32·81	0·18	0·36	„	„	36·5	42	92	0·396	37·4			17·5	„	27·7	68·8	41	0·658	22·5			19 (*n. c.*)
	137	20	70	30				„	37·5	40·1	90	0·416	36·5			7	„	28	72	43	0·691	23·6			19 (*n. c.*)
	130	20	85·29	12·70	0·28	1·15	0·50	„	34·1	14·6	91	0·376	36·9			7·5	„	25·7	47·5	40·5	0·552	25·6			15
	131	20	90·64	8·37	0·31	0·35	0·18	„	30·4	16·3	83	0·366	33·7			„	„	23·6	48·8	43·5	0·541	23·9			13·5
Special Brasses	138	20		Manganese Brasses					46·9	24	113	0·440	45·6			„	„	33·9	28	61	0·556	33·5			12·5
	351	20							50·8	26				20·2	—	„	„	44·4	44·5				16·7		„
	352	20							58·1	17·4				21·1	—	„	„	49·4	28				19·85		„
	353	20							64·8	5				22·6	—	„	„	56·1	9·5				19·95		„
	355	20	63·01	35·96	„	0·31	0·08	*Ni*=1·04	38·1	34				14·45	40·2	„	„	31	62				12·9	34·5	„
	360	20	61·31	37·24	„	0·54	0·30	*Sn* 0·61	44·7	20				15·6	44·1	„	„	35·4	22				13·7	38·5	„
	141	20	60·92	37·94	„	0·22	0·13	*Sn*=1·09	42·6	25·8	109	0·408	44·1			5	„	33·3	37·3	60·5	0·552	33·3			10
Bronzes	121	20	98·22	„	1·47	„	0·27	*P*=0·006	33·2	19·3	88	0·370	35·6			11·5	„	26·2	51	48	0·543	26·4			22 (*n. c.*)
	122	20	96·81	„	3·14	„	0·12	*P*=0·005	36·5	25	98	0·372	39·6			8	„	29·8	50	53	0·561	29·1			19 (*n. c.*)
	123	20	91·85	„	7·80	„	0·25	*P*=0·005	44·8	39	120	0·372	48·5			9·5	„	35·1	73	64	0·549	35·2			20·5 (*n. c.*)
	124	20	90	2·00	8·00	„	„	*P*=0·005	47·4	37	120	0·394	48·5			10	„	35·6	71	64	0·553	„			23·5 (*n. c.*)
	125	20	88·31	2·15	9·15	„	0·29	*P*=0·007	52·3	30·3	130	0·402	52·7			6·5	„	40·1	72·5	69	0·578	38			17
Aluminium Bronzes	126	20	97·70					*Al* 1·98	32·1	19·2	90	0·356	36·5			13·5		24·5	53·3	43·5					21 (*n. c.*)
	127	20	05·94					*Al* 3·87	40·8	31·5	105	0·389	42·6			13		30	75	47·5					24 (*n. c.*)
	128	20	94·47					*Al* 5·33	51·4	21·4	130	0·394	52·7			6·5		36·2	52·4	52					26 (*n. c.*)
			92·13					*Al* 7·45										43·2	54						30 (*Frémont*)
			91·95					*Al* 8·02										46·2	43·5						30 (*Frémont*)

Samples worked out of Castings.

les worked out of Castings

…pression in %	Compressive Strength. Compression in %	Impact Strength	Taken from hollow Castings: Number of Sample	Dimensions of Sample	Gauge Length	Bending-Strength	Flexure	Tensile Strength		Compressive Strength. Compression in %	Impact Strength
…er …2	kg per mm²	kg/m	No.	mm	mm	kg per mm²	mm	mm in Dia.	kg per mm²	kg per mm²	kg/m
			I–III	60×60	1000	28·60	14·73	48	16·43		
		95·7	IV–VI	50×50	1000	27·27	16·27	38	16·35		81·6
1 5	66·50 5·5%	24·0	VII–IX	40×40	1000	26·17	21·00	30	16·68	63·80 17·5%	20·8
/0 2 /0	73·00 3·3%	9·0	X–XII	30×30	1000	27·56	26·57	20	17·63	67·06 14·0%	7·2

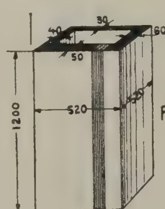


Fig. 3.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

V$^{\text{TH}}$ CONGRESS, COPENHAGEN 1909.

VII1

THE UTILISATION OF THE MAGNETIC AND ELECTRIC PROPERTIES OF MATERIALS IN CONDUCTING MECHANICAL TESTS.

Report by **A. Grünhut** and **Dr. J. Wahn**, Vienna.

Translated by Dr. H. Borns, London.

The manifold relations which exist between the phenomena of magnetic, dielectric and mechanical polarisation have induced Dr. von Hoor to propose a series of methods for testing, based upon these relations, to the Budapest Congress of the International Association for Testing Materials.

With regard to ferro-magnetic materials, for instance, Dr. von Hoor considered that the changes which the curves of magnetisation and of permeability, the static and viscous magnetic hysteresis, the remanent magnetism, the coercitive force, and also the electric conductivity undergo when the materials are mechanically stressed, should afford suitable criteria for judging the mechanical properties of those materials.

Dr. von Hoor submitted a resolution to the Congress to the effect, that it appeared advisable to study the magnetic and electric properties in conjunction with the mechanical properties, and that a Commission be appointed for the purpose of collecting the respective data, of laying down a programme for the investigation, and of examining in which way the magnetic and electric properties could be utilised for defining and describing technically applied materials.

The authors have only been able to deal with the first part of their task, and they have grouped in an appendix to this report an extract from the most important researches concerning the interrelations between the physical properties of the magnetic metals in so far as they affect the problems of the practical testing of materials.[1])

This concise compilation will suffice to mark the manifold character of the phenomena in question and the impossibility of deducing, from the actually available data, exact relations between the physical properties which might serve as guides for mechanical testing.

A large number of experiments have been conducted with the object of investigating the influence of elastic stress (tension, compression, torsion) on the magnetising curves of iron and steel, the test-rod or wire being submitted to external forces during magnetisation. The influence of those stresses upon the magnetisation of iron cannot definitely be expressed, however. Weak magnetism, e. g., is increased by tensile stress, strong magnetism is diminished; the curves change with the past history of the material; it makes a difference whether or not the iron has been put under stress before the magnetisation. Compression has in general the opposite effect to tension.

It is not immaterial for the result of the test whether the load was during the magnetising process slowly being put on the specimen or being taken off; in this respect we might speak of magneto-elastic hysteresis.

Not only the temporary, but also the remanent magnetism left in the iron after the completion of the magnetising process is influenced by tensile stress; the relation is not simple, however, and depends upon the intensity of the previous magnetisation.

It has long been known that an iron wire or rod alters its length and volume when under magnetisation; these effects give us an insight into the molecular structure of the material. The final total value of the changes of length naturally depends upon the intensity of the magnetisation, the original dimensions of the specimen, its elastic history and, not in last instance, upon temperature variations.

[1]) The compilation is based upon the respective literature published in periodicals, and upon Ewing, Magnetic Induction in Iron and other Metals and Winkelmann-Auerbach, Handbuch der Physik, vols. IV and V.

A test-rod expands as the magnetisation is increased to its maximum length and contracts then again to its original length; at relatively high magnetisation we may even notice a shortening of the rod. In this phenomenon, as well as in other magnetic phenomena, we may speak of a hysteresis of the variation of length with regard to the magnetisation, or in other words: the changes in the length of a test-rod are not the same with increasing magnetisation as with decreasing magnetisation. These conditions are entirely altered when we superpose circular magnetisation on the longitudinal magnetisation, by passing a current through the rod, for instance.

Effects analogous to those produced by tension and compression are observed, when the specimen is subjected to cyclic torsion while under magnetisation. There is a pronounced hysteresis between magnetisation and torsional stress. It is further noteworthy that magnetic metals exposed to shear or torsion show different magnetic permeabilities in the directions of the different axes.

A large number of measurements have been made with the object of ascertaining, whether and in which way the elastic constants of iron and steel wires are influenced by magnetic forces. The only fairly established fact is that with increasing magnetisation the moduli of elasticity, both for tension and shear, increase rapidly at first and more slowly afterwards, somewhat after the manner of the changes in permeability; the variations in the moduli are not large, however.

We should here draw attention to the experiments which L. Fraichet[1]) brought before the IV. Congress of the International Association for Testing Materials, Brussels, **1906**. This new method of testing makes use of a galvanometer and a coil, and relies upon the fact that large changes occur in the magnetic properties of a body under tension when we approach the elastic limit. Fraichet thus hopes accurately to determine the elastic limit.

We have further to mention the influences of concussions and of the technical treatment of magnetic materials upon their magnetic properties; the appendix refers to these points.

Both the temporary magnetism and the remanent magnetism are strongly influenced by variations in temperature.

[1]) Nouvelle méthode d'essai des métaux magnétiques.

In general the temporary magnetism, induced by a certain magnetising force, increases with rising temperature, rapidly at first, then more slowly, up to a maximum, to decrease rapidly again when this temperature is exceeded. On cooling, the magnetism re-appears, re-attains its maximum, and diminishes to the original value on continued cooling.

When the magnetism is regarded as a function of temperature, there is therefore for every magnetising force a critical temperature at which the magnetism reaches its maximum; and there is, conversely for every temperature a critical magnetising force, below which the magnetism is greater for higher temperatures, and above which it is smaller for higher temperatures.

The increase in the magnetism is all the more considerable, and its final diminution all the more abrupt, the lower the magnetising force, at which the temperature curves was plotted.

The remanent magnetism is diminished by heating, and is altogether lost by heating to high temperature.

In this connection we have to distinguish again between first heating and repeated heating: the latter effect is reversible, the former not.

This applies only as long as the extreme temperature does not exceed a certain limit, however. When the material is kept at strong glow, it loses its magnetism permanently after repeated cycles. Repeated annealing is hence an excellent means for producing demagnetisation.

Important is also the influence which the hardening temperature of steel exercises upon the magnetisation. Holborn has found, that rods remain unchanged and soft when the hardening temperature lies below 750^0 C. When the hardening is effected at temperatures ranging from 750 to 850^0 C., the remanent magnetism rises to fourfold its value; above 850^0 C. its diminishes again; and when the steel is hardened at 1000^0 C. the remanent magnetism rises to about $^2/_3$ of its maximum value only. The temperatures of hardening most favourable for permanent magnetisation lie between 750 and 850^0 C.

The influence of temperature on the hysteresis can be deduced from its effects upon the temporary and the remanent magnetism (further particulars will be found in the supplement)

It should be mentioned that, as in almost all magnetic effects, the cyclic temperature variations show a hysteresis phenomenon. This temperature-hysteresis is small, however, and attains higher values only within those temperature intervals, in wich the magnetism disappears or re-appears. This interval amounts in the case of iron to about 10^0 C. in general, in the case of steel to 20 or 30^0 C.

The influence of mechanical stress upon the magnetic hysteresis of iron and steel has not sufficiently been studied so far. Researches of this kind should, however, furnish definite criteria for the characterisation of magnetic materials, particularly iron and steel. It would therefore be most desirable in our opinion to ascertain, by means of adequate experiments, in which sense the hysteresis work, i. e. the work which has to be done in order to orient the molecules of iron, etc., is affected by mechanical stress — within the limit of elasticity.

The experimental data so for available show that magnetism is in definite, direct or indirect, relations to almost all physical phenomena, to mechanical stresses of all kinds as well as to influences of temperature, chemical composition and structure. The interrelation between these various phenomena is not sufficiently uniform, however, so far as our actual experience goes, to allow us to determine, in the sense of the proposal made by Hoor, the physical properties of a magnetic material from magnetic tests.

Though, therefore, the results so far established do not satisfy those far-reaching requirements, the collected data are sufficiently valuable to form the foundation for devising practical magnetic and electric methods for testing materials, methods which offer the advantages over the customary mechanical methods, that they are sensitive and simple, that they do not necessitate destruction of the specimen, and that they can easily be repeated.

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VII₂

FERROMAGNETISME AND THE SUDY OF METALS AND ALLOYS.

By Professor **Pierre Weiss**[1]), Zürich.

Translated from the French by Dr. H. Borns, London.

The magnetic properties have been of great service in the study of metals and alloys. Yet, up to the present, these properties have apart from a few exceptional cases[2]), been utilised merely in a qualitative sense, for the determination of the temperatures of the appearance and of the disappearance of magnetism. That magnetic measurements are not more widely applied is due to the fact that, in the absence of a satisfactory theory of ferromagnetism, it is not generally recognised which of the various quantities, intensity of magnetisation, induction, susceptibility, permeability, coercitive field, remanent magnetism, and which of the curves and cycles may be regarded as really characteristic. Up to the present, moreover, the experimental technics of the study of metals and alloys had not been worked out.

I propose to fill up this double gap. I shall subsequently examine the magnetic transformation from the standpoint of the phase-rule, and I shall demonstrate, with regard to ferro-nickels and carbon steels, the results which we may expect to obtain from the application of quantitative magnetic methods.

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1) Summary of an article published in the Revue de Métallurgie, vol. 6, 1909.

2) Kurt Lewkonja, Zeitschr. f. Anorgan. Chemie, 59, page 293, 1908. Maurer, Revue de Métallurgie, 5, page 728, 1908.

The Theory of Ferromagnetism.

I shall confine myself to a brief outline of the kinetic theory of magnetism which Langevin has elaborated for paramagnetic bodies and which I have extended to ferromagnetic bodies; the demonstrations will be found in the original memoirs.[1]) Langevin assumes that the molecules of a paramagnetic gas have an invariable magnetic moment. These elementary magnets are subjected at the same time to an exterior field which tends to orient them, and to thermal agitation which continuously tends to destroy the effects of the field. Under these conditions the intensity of magnetisation, or briefly the magnetisation, that is to say the resultant magnetic moment of the magnets contained in a cubic centimetre, depends both upon the field and upon the thermal agitation, that is, upon the temperature. The magnetisation has a maximum, corresponding to the complete alignment of the little magnets, which maximum will be attained either in a field of infinite intensity at any temperature, or in any field at absolute zero when the thermal agitation does no longer exist. This maximum we shall designate the absolute saturation I_0. For all realisable fields the magnetisation grows proportionally to the field. It is only in fields of much greater intensities that the want of proportionality between magnetisation and field and, all the more strongly, the approach of saturation make themselves felt.

The kinetic theory of Langevin constitutes for paramagnetism what the kinetic theory of Daniel Bernoulli is for the compressibility of perfect gases. Van der Waals has extended this latter theory to fluids in general by suggesting a hypothesis concerning the mutual action between the molecules of the gas which were so far regarded as independent. This hypothesis finds an expression in the interior pressure which, added to the exterior pressure explains the great density of liquids with the aid of the properties of gases. In an analagous manner I propose a molecular field which, added to the exterior magnetic field, explains the strong magnetisation of ferromagnetic substances by the laws of paramagnetism.

This hypothesis enables us to submit the ferromagnetic phenomena to calculation, and it leads to the following conclusion

[1]) Langevin, Ann. Chim. Phys. (8) 5, page 70, 1905. Pierre Weiss J. de Phys. (4) 6, page 661, 1907, and Physikal. Zeitschr. 9, page 358, 1908

Below a certain temperature the stable condition of the molecular structure, as left to itself, without any exterior field, does not correspond to zero magnetisation, but corresponds on the contrary to a finite magnetisation value I which is a function of the temperature.

We are thus asked to familiarise ourselves with the idea of a spontaneous magnetisation, though experience does not know of magnetism except as a consequence of the actual or previous application of a magnetic field. There is nothing surprising in this thought; for analogously a liquid can exist with its strong density, when there is no exterior pressure, but merely the interior pressure. But we have to ask ourselves, how it is that our senses do not perceive this magnetisation in a piece of iron or steel when in the neutral state. We have to bear in mind that in what was said there is nothing to determine the direction in which the spontaneous magnetisation should reveal itself. Left to chance the magnetisation will assume all the possible directions in some small portion of the body which will hence appear neutral by compensation.

Chance intervenes by the mechanism of the confused crystallisation of industrial metals. To be brief, we may state that the theory lends itself without difficulty to the explanation of the ferromagnetic properties of an isolated crystal and to the synthesis of those properties in apparently isotropic crystalline materials.

We understand that the exterior field does not call forth the magnetism, but renders it perceptible. The spontaneous magnetisation, in its true magnitude, will only be observed when the little magnets have all been made exactly parallel throughout the substance, and a very intense field is required for this purpose. The spontaneous magnetisation is the saturation for the given temperature.

The belonging to the saturations different temperatures, of which we speak in this connection, must not be confounded with the absolute saturation of Langevin. The two terms have the same meaning only at absolute zero.

The spontaneous magnetisation I diminishes when, with rising temperature, the thermal agitation becomes more intense; at a certain absolute temperature θ it will dwindle to zero, rapidly

in the last stages. This law of thermal variation is illustrated in Fig. 1.

The points marked on this diagram refer to experiments made with magnetite.

For this substance then the theory holds accurately. In the case of the metals there is concordance as regards the general appearance of the curve. The experimental study of their saturation as a temperature function will supply the second approximation, as the precise study of the compressibility of fluids has led to correct the equation of van der Waals. The actual theory suffices to bring out the physical meaning of the magnetic data. In the applications which will be discussed lower down we must, however, have recourse to the experimental curve of each substance.

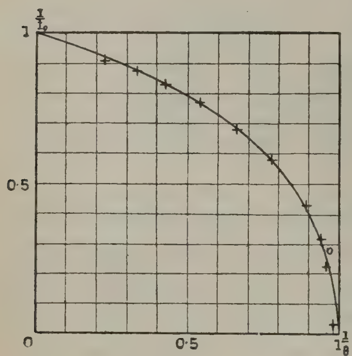

Fig. 1.

There is hence no essential difference between a magnetised body and a magnetic body, i. e. a strongly magnetisable body. Both are magnetised to saturation, but in the one the magnetisation is co-ordinated, while it is confused in the other.

Beyond the temperature θ, at which the spontaneous magnetisation is lost, the molecular magnets can still act upon one another, but the molecular field is not in itself sufficient to produce magnetisation. The molecular field serves merely as a supplement to the exterior field. This is the β region of the not independent ferromagnetism. In the γ iron of Osmond and in the δ iron of Ball the molecular magnets no longer enter into mutual action; these states are paramagnetic. The interpretations which have just been indicated are based upon experimental evidence.

The theory which we have outlined permits us to state the specific character of a ferromagnetic body. In the α region the substance is characterised by the law expressing the variation of the spontaneous magnetisation as a function of the temperature. In the β region the theory makes use of a single new factor, the constant of Curie. The residual phenomena have not so far been brought into complete accord with the theory. But pyrrhotine crystals

have supplied additional experimental information and have shown that there is only one more constant to be taken into consideration, the coercitive field. The curve and the two constants comprise the whole description of a ferromagnetic body.

We are not confronted, it will be seen, by the formidable complexity of the curves and magnetisation cycles of the electricians with their thermal variations. The reason is that the latter magnitudes embody, in addition to the essential properties, the influence of the crystalline structure, of cavities, of non-magnetic enclosures, and of strains, factors which are all secondary for the physics of the material.

As regards the practical standpoint of the study of metals and alloys the really applicable characteristic quantities are of two kinds: those which can be determined in a mixture of several phases as well as in a body containing only one phase, and those which are additive.

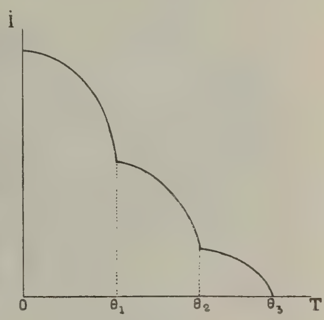

Fig. 2.

The temperature θ of the loss of the ferromagnetism is a case of the first kind. The experimental curve of the magnetic variation, as a temperature function, of a substance which consists of three ferromagnetic phases will be of the type of Fig. 2. The temperatures θ_1, θ_2, θ_3, marking the loss of spontaneous magnetism by the three phases, can directly be read off on this curve with the aid of the three characteristic vertical tangents. The magnetisation itself is evidently additive at any temperature for the three phases which make up the alloy. As the nature of the alloy is given by θ_1, θ_2, θ_3, it will be sufficient to measure three ordinates in order to deduce the composition of the alloy, the magnetic properties of each phase, taken separately, being assumed to be known.

The constant of Curie, which concerns the substance at a higher temperature than θ requires a more delicate measurement. There is no reason for the present to class this constant with the practically applicable characteristics. The coercitive field has no simple meaning in the case of mixtures; it is the field for which

the contrary magnetisations of the different portions compensate one another.[1])

Experimental Technics.

The arrangement which I have devised in order to determine, with the least difficulty and with great precision, the variation of the intensity of magnetisation at saturation as a temperature function, is based upon the following property. When an oblong ellipsoid of rotation of the substance is placed obliquely in a magnetic field, which is sufficiently powerful to produce saturation, this field exerts upon the ellipsoid a couple which varies with the inclination of the great axis to the field. For a certain inclination this couple has a maximum C_m, which is, apart from an instrumental constant A, equal to the square of the saturation intensity of the magnetisation.

$$C_m = A\,I^2$$

When therefore the ellipsoid is suspended by a torsional spring, the relative values of I^2 can be read off by the deflections of the spring. Neither the orientation, nor the exact value of the field need be known, provided that the field can be varied sufficiently to ensure that saturation is really attained.

We have further to produce the necessary high temperature within the small space available between the pole-pieces of an electromagnet. Preliminary experiments have convinced me that an electric surface formed by a platinum helix of vertical axis, embedded in kaolin and closed above, somewhat similar to the furnace which Pierre Curie employed in his classical researches, does not yield a sufficiently uniform temperature.

In a furnace, 7 cm in length and 13 mm in external diameter, I have observed, in the region of greatest uniformity, temperature fluctuations amounting to 50^0 within space of two centimetres, the mean temperature being about 500^0. I therefore wound the platinum, suitably insulated, on a sleeve of red copper, about 1 mm in thickness, and I observed that the temperature variations, within the same space, had diminished to 1^0. Owing to the oxidation of the copper this furnace can only be used at temperatures up to

[1]) This statement does not imply that this field could not be utilised in a certain way; compare Maurer, Revue de Métallurgie, loc. cit.

00⁰. With a sleeve of silver the temperature may be pushed up) 900⁰, and with a sleeve of platinum up to 1400⁰. In the first wo furnaces mentioned the platinum strip of 0·3 by 0·8 mm which forms the bifilar winding is insulated from the metallic leeve by mica and is coated with kaolin. In the third furnace oth the resistance and the cylinder consist of platinum, and the nsulation is all kaolin.

The insulation is in his instance a rather nore delicate matter; once constructed the ıpparatus can, however, serve for many experiments.

The temperature is letermined with the iid of a thermocouple of platinum and platinum-rhodium, of 0·3 mm, insulated by neans of capillary tubes of fused quartz; the unction is quite close o the substance. The electromotive force is neasured with a potentiometer.

Fig. 3 shows the powerful electromagnet[1]), mounted on a pivot, which has served for these experiments. Between the polepieces

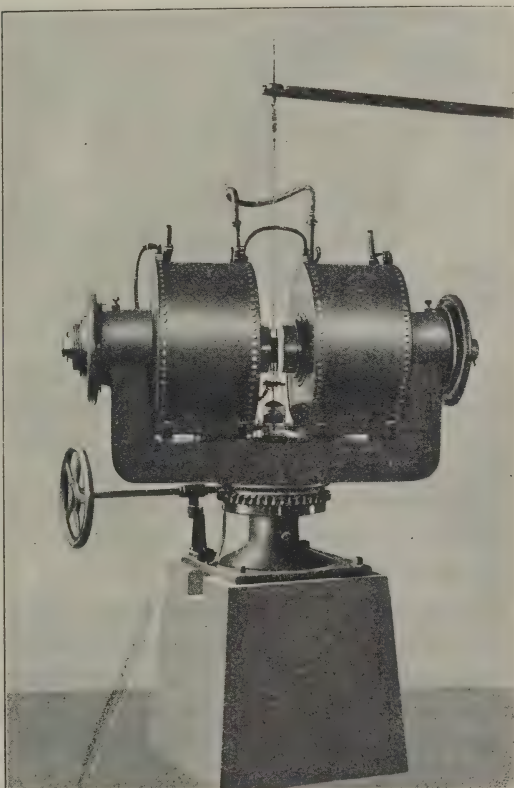

Fig. 3.

we notice the electric furnace and the mounting in the form of a stirrup, suspended by a torsional spring which supports the substance and the mirror which marks the deflections. The constant A of the instrument could be calculated a priori, if we knew

[1]) J. de Phys. (VI) 4, p. 453, 1907.

the exact dimensions of the ellipsoid. Experience proves, however, that the relative values remain exact when the ellipsoid is realised with a rough approximation. It will moreover be understood that an ellipsoid of three unequal axes may do as well as an ellipsoid of rotation. It is therefore advantageous to substitute, for the calculation of the constant A, a standardisation of the apparatus, made independently in absolute measure at the ordinary temperature. For this purpose I have measured the quantity of electricity which is induecd when I introduce the ellipsoid into an accurately constructed solenoid which is placed in the axis of the field of the electromagnet.

Is the Magnetic Transformation a Change of State?

It is indisputable that the material undergoes a profound transformation by the loss of its magnetic properties. But is this transformation a change of state analogous to fusion or evaporation? If that were so, we should have two phases in equilibrium during the transformation. When the composition of the two phases is the same, that is in particular in the case of a pure metal, the transition from one phase to the other should take place at a definite temperature, under absorption of a quantity of heat proportional to the quantity of material transformed. The question therefore presents itself in this shape: Are the α and β states two distinct phases?

In general this question has more or less explicitly been answered in the affirmative since the publication of the work of Osmond, in which the two transformations, $\alpha\ \beta$ and $\beta\ \gamma$, of iron manifest themselves on the cooling curves by a liberation of heat apparently analogous to the heat liberation during solidification.

Tammann has said quite recently[1]: "that the loss of magnetic properties is, in an entirely general manner, connected with the transformation of a crystalline magnetisable species into a heteromorphous not magnetisable species." H. Le Chatelier[2], on the contrary, believes "that we are dealing with a phenomenon which is altogether different from ordinary transformations. The latter affect on the whole all the properties of the bodies at the

1) Tammann, Zeitschr. f. Phys. Chemie, LXV., page 79, 1908.

2) Revue de Métallurgie, I., page 213, 1904.

ame time. But we have as yet not been able to demonstrate any ıfluence of this transformation on the dilatation, nor on the lectric conductibility, nor on the thermoelectricity of iron. Another .nd graver difficulty is that this transformation is progressive."

On the strength of their profound crystallographic studies)smond and Cartaud[1]) have taught that the α iron and the β :on are isomorphous. This statement is the negation of the xistence of two distinct phases α and β; but it is not acceptable, : we take the term isomorphism in its usual sense. Isomorphism vould in fact imply that we could, at the same temperature, btain mixtures of α and β iron in different proportions, which vould be contradictory to the reversibility of the variation of the aturation-magnetisation with temperature, such as I have found ɔ hold exactly for pure iron.

In more recent publications[2]) these scientists come back to ıe opinion "that the three allotropic varieties of iron, although rystallising in the cubical system, present marked specific haracters and cannot have the same internal structure".

Yet, when we examine these characters, we cannot help oticing that the differences between α iron and β iron consist in hat in the latter were not found certain properties of the α iron, vhile all the observed characteristics are the same. This statement, ombined with the remark of Osmond and Cartaud, concerning ickel, "we have not observed any crystallographic differences etween the two states of this metal", shows that there is no ıct which opposes the crystallographic identity of the α and β tates of one and the same ferromagnetic body[3]).

The theory of ferromagnetism does not in any sense suggest ıe distinction of the two phases α and β. Ferromagnetism is nalogous to compressibility of fluids, but not identical with it. : is moreover precisely the comparison of the two kinds of

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[1]) Osmond, Ann. des Mines, XVII., page 110, 1900. Osmond and Carıud, ibid. XVIII., page 113, 1900.

[2]) Osmond and Cartaud, Journal of the Iron and Steel Institute, 1906, age 486; and C. R. CXLII., page 1531, 1906.

[3]) I take this opportunity to point out the interest which attaches to .agnetic measurements made on crystals of iron. I commenced this study with ɔme beautiful crystals which I owe to Mr. Osmond, and I appeal to the indness of others who should be able to place further specimens at my disposal ı order that I may successfully continue this research.

phenomena which can help us to clearness. The phenomenon whose laws most resemble the variation of ferromagnetism as a temperature function is the thermal variation of the density under the critical pressure.

The two phenomena are plotted together in the diagram Fig. 4. Their relationship is evident. There is, on the other hand a manifest difference between the dotted curve which represents the change in the density of a fluid at pressures below the critica pressure, and the straight-line portion characteristic of the lique faction. If we knew liquids exclusively at pressures above th critical pressure we should not have any possibility of distinguishin two phases.

In other words, as long as the pressure remains below th critical pressure, the formula of van der Waals gives, for th same pressure and the same tem perature, two different densit values corresponding to stabl conditions. The theory of ferro magnetism, on the contrary, neve gives more than one stable valu of the magnetisation for a syster of temperature and field values

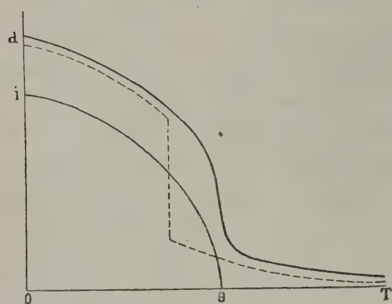

Fig. 4.

Since then the α state an the β state are not two differer phases, it is appropriate not t trace the locus of the temperature θ in the same way a the lines of fusion or of change of state in the proper sense lines along which two phases are in contact.

With respect to the βγ transformation we have for th present no reason to suspect its allotropic nature. The γδ trans formation, still little studied, has not so far been introduced int diagrams.

Nature of the Thermal Phenomenon accompanying the αβ Transformation.

Since the false analogy between αβ transformation and change of state has crept in owing to the apparently simil manner in which the two phenomena seem to manifest themselve on cooling curves, it will be of interest to express the therm

change which goes together with the loss of ferromagnetism in a more precise fashion. The mutual energy of the elementary magnets contained in unit volume is

$$E = -\frac{1}{2} H_m I,$$

where H_m is the molecular field and I the spontaneous magnetisation. To what would represent the specific heat if the substance were not magnetic, we have to add

$$C_m = \frac{D}{J} \cdot \frac{dE}{dt},$$

where D is the density and J the mechanical equivalent. This term can be determined by purely magnetic experiments. It is very small at low temperatures, grows rapidly in the neighbourhood of θ, and falls rapidly to zero at that temperature θ. The thermal phenomenon consists therefore in a heat of demagnetisation, expended during the whole temperature interval ranging from absolute zero to θ, with a discontinuity in the true specific heat at this temperature. The following table gives the discontinuities $\overset{\theta}{Cm}$, and the temperatures θ, determined:

Magnetically	Calorimetrically
Iron	
$\overset{\theta}{Cm} = 0{\cdot}136$	$\overset{\theta}{Cm} = 0{\cdot}112$
$\theta = 753 + 273^0$	$\theta = 758 + 273^0$.
Nickel	
$\overset{\theta}{Cm} = 0{\cdot}025$	$\overset{\theta}{Cm} = 0{\cdot}027$
$\theta = 376 + 273^0$	$\theta = 376 + 273$.
Magnetite	
$\overset{\theta}{Cm} = 0{\cdot}048$	$\overset{\theta}{Cm} = 0{\cdot}050$
$\theta = 588 + 273^0$	$\theta = 580 + 273^0$.

This concordance confirms the theory in a remarkable manner.

Application.

Alloys of Iron and Nickel. The properties of iron-nickel alloys may graphically be represented as in fig. 5. The $\beta\,\gamma$ transformation of pure iron is reversible (point A). The addition of nickel to the iron has the effect of lowering this transformation

temperature and of splitting it, in as much as the phenomenon takes place at higher temperature on heating than on cooling. The transformation line A B for cooling and the transformation line A C for heating divide the area into three regions: in the region I the material exists only in the state $\alpha\,\beta$, in region III only in the state γ, in region II it can exist in both these states. This system therefore affords an example both of a solid solution of a ferromagnetic metal in a paramagnetic metal (Ni in Fe γ) and of one ferromagnetic metal in another ferromagnetic metal (Ni in Fe $\alpha\,\beta$). The solubilities appear to be limited only by the limits A C and A B of the existence of the two states of iron.

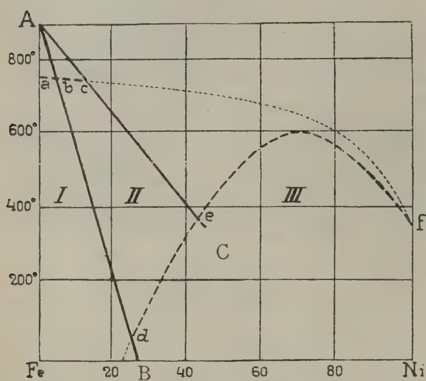

Fig. 5.

Each of these two systems of solution is ferromagnetic. The locus of the temperature θ can therefore be marked for both ot them: it is a b c f for the first, and d e f for the second. The line d e f is well known by the study of reversible ferronickels. The portion a b c of the line a b c f is alone accessible and has only been observed by the not very exact thermal method[1]).

Quantitative magnetic experiments will effectively check the above expressed views, by ascertaining the difference in the nature of the phenomena representend by a c and c e and the corner at e of the line of the loss of magnetism a c e. If, as Guertler and Tammann[2]) have supposed, the compound Ni_2Fe, which is still doubtful, really exists, it should reveal itself in the course of these quantitative measurements. It will be recognised that this theory is in agreement with Guilleaume, who regards all these anomalies, and notably those of extension, as imputable to the iron.

Iron and Carbon. The diagram of Roozeboom comprises a pretty large number of ferromagnetic substances of which ferrite

[1]) Osmond. Roy. Soc., Proc., London, 47, pages 23, 138; 48, page 1, 50, page 121.

[2]) Guertler and Tammann, Zeitschr. f. Anorgan. Chemie, 45, page 205.

has alone been studied. The properties of cementite F_3C are almost entirely unknown. This applies still more strongly to the martensites which are solutions of carbon in iron which is in the $\alpha\beta$ state. The austensites which are solid solutions of carbon in γ iron, will experimentally be discovered by a deficit in the total magnetisation. Of the two other constituents of Osmond finally, sorbite and troostite, whose natures remain obscure in spite of specific well-defined characteristics, we shall no doubt learn more when we have recourse to quantitative magnetic measurements. It will be granted without our insisting any further, that ferromagnetism places further resources at our disposal for the study of the system iron-carbon[1]).

[1]) Compare the Reports on this question presented by Osmond and Cartaud and by Osmond to the Brussels Congress.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

V^TH CONGRESS, COPENHAGEN 1909.

X1

PROGRESS IN THE METHODS OF TESTING HYDRAULIC CEMENTS.

Official report presented by **R. Feret**, Boulogne-sur-Mer.

(Translated by A. R. Liddell, Charlottenburg.)

At the IV. Congress of the International Association held in Brussels in 1906, Committee No. 22 presented and obtained the adoption of the results of extensive labours, in which they had been engaged since the foundation of the Association, with a view to the adoption of uniform methods for the testing of the different materials the study of which enters into the domain of this latter body.

But in view of the difficulties of all kinds inherent in a tentative international unification of the kind, the Committee has been able to give official recommendation to hardly any other methods than to such have been in use for a long time and already have the support of established custom, and such a solution can only be of the provisional character inseparable from every idea of progress.

In this report it is proposed, in so far as the testing of hydraulic cements is concerned, to pass in review the methods that are capable at a later time of being advantageously added to or substituted for those of the Committee, whether because they have not been thought of till after the conclusion of the latter's

labours, or because, although already more or less known, they were not considered to have stood the test of experience to such a degree that they could at this stage be sanctioned by the Association.

In view of the very narrow bounds which have been set for this work, the reporter will confine himself to an examination of the principles underlying the methods, without going into the details of the conduct of the tests.

Chemical Composition.

Hitherto, the International Association have not concerned themselves with the methods applied to the analysis of the hydraulic cements and, moreover, it is thought that opinions may differ as to the opportuneness of the eventual inclusion of these in this kind of investigation, which seems to belong rather to the domain of pure chemistry, than to that of technology. The conditions for the reception of the products in question, however, always contain clauses relative to the chemical composition of these, and it often happens that difficulties arise from the want of uniformity in the percentage of this or that simple element found in several different laboratories. Also the Association should ask themselves, whether, in the case of limes, cements, and suchlike products, the work of progress would not be furthered by the indication of a practical and uniform standard method of chemical analysis, which would be appealed to in contested cases, without such method at the same time arrogating to itself the right to take the place of all others that the individual experimenter might judge to be better calculated to attain some special end he might have in view, whether the question at issue should be the determination of elements only occasionally met with in the cement, or analyses of great precision, or should on the contrary bear reference to rapid and more or less approximate chemical tests.

A start in this direction has already been made in the United States of America, where an important piece of work has been accomplished in the fixing of a uniform method for the analysis of the crude constituents, as of the manufactured products of the hydraulic cement industry.

At the same time it would no doubt be convenient that the Association should take the question into consideration, as to whether they should also indicate methods for certain chemical tests of a more conventional character, such, for instance, as the weight constituent of soluble silica, the proportion of which evidently depends on the conditions under which its dissolution is attempted.

Tests of this kind attach to investigations into chemical constitution, that is to say to the part played by the various elements and to their grouping, an important question but one which may still be made the subject of lengthy discussion; on the other hand the chemical composition of a material, as expressed by the different percentages of the primordial elements which it contains, can indeed be exactly determined in each case, but affords very little clue to the quality of the product.

Specific Gravity.

Specific gravity is a precisely defined quality, and there is no lack of methods for its exact determination, so that further progress of any importance in this direction is hardly conceivable.

The question is far from being exhausted, however, and the value to be attached to such determinations in view of the differentiation of the hydraulic cements among themselves, or of the appreciation of their qualities is still under discussion. Opinions differ also, as to whether it is better to work with the cement in its market condition or after recalcination.

Apparent Density.

Unlike specific gravity, apparent density is an entirely conventional conception and varies with the method of measuring it.

The method adopted by the International Association at the instance of Committee No. 22 is one that gives the weight of unshaked litre under very comparable conditions, and does not seem to stand in need of improvement.

As in the foregoing case, however, there is room for discussion as to the utility of this test, as well as of that of the simultaneous determination of the weight of a shaked litre under certain clearly defined conditions.

Fineness of Grinding.

The use of sieves for the separation of hydraulic cements into grains of different sizes and for the determination of the proportions of each of these has been the subject of numerous criticisms. The two principal of these bear reference, on the one hand to the extreme difficulty of making the metallic meshes perfectly regular and of a rigorously defined uniform type as regards thickness and spacing of the wires, and on the other to the impossibility of separating the finest particles contained in the powdery substance by means of sieves with very closely spaced wires.

Various experimenters have endeavoured to effect a methodical separation of the powders by levigation experiments, made, either by shaking them in a liquid, which is then poured off with the fine particles remaining in suspension after a fixed period of repose, or by working them in a liquid or gaseous current of regulable speed, which carries away the finer and lighter particles. By a variation of the period of repose in the first case and of the speed in the second, the powder may be separated into grains of different sizes to any desired degree.

A method of sufficient simplicity, however, which above all can be defined in a sufficiently precise manner in all its details, so that the Association could at once recommend it from the point of view of international unification of tests of this kind, does not appear to have as yet been discovered. At the most, expression may be given to the opinion that the use of a current of air would probably be more practicable than that of a liquid.

The question has, moreover, been already submitted to the study of a special commission.

Homogeneity.

The experiments to ascertain whether a cement is homogeneous and, in case of need, to determine the foreign matter contained in it, which were not foreseen by Committee No. 22, should admit of being made by different methods according to the nature of the impurities suspected, and their strict unification does not therefore appear to be possible.

The methods most often resorted to consist in the separation of the powder, either into grains of specific weights rising by

egular gradations according as they float or sink in liquids of suitable densities, or into grains of different sizes, by sifting or by evigation, followed by the examination with the microscope or by the separate analysis of the different kinds of grain obtained.

Constancy of Volume.

Numerous methods have been applied consisting in the moulding of the paste in the forms of cakes with thinned edges, of little balls, or of cylinders, and in the exposure of these test-samples to the action of air, water, or steam, either hot or cold.

It is clear that these different tests are not all equally severe; often indeed their results may be such as to vary the order of the cements as classed by them.

The only ones which are in somewhat more general use are the test on cakes immersed in cold water, which, however, allow products of doubtful quality to pass unchallenged, and the boiling water test on cylinders confined in a thin divided metallic covering provided with two long amplifying pointers the increase of the interval between which is measured (Le Chatelier method). In view of simplicity and rapidity, and the concrete numerical form in which its results are given, this method constitutes a real progressive step, and it has been quickly adopted without opposition in most of the specifications of conditions of delivery.

As to the methods which consist in the very exact measurement of the length variations of small prismatic bars, their very delicacy limits their application to certain investigations of a scientific nature, and, moreover, they do not appear to be altogether above criticism.

A special commission is still studying the question of tests on constancy of volume.

Action of Sea Water.

A method at once sure and rapid of determining the capability possessed by hydraulic cements of resisting the decomposing action of sea water and sulphurous waters has not yet come into general use, and the method commonly employed consists simply in immersing the mortar into sea water and observing it for as long periods as possible. The results given by this test vary, however, according to the composition of the mortar and to

the conditions of its immersion, and the experimenter often has to wait for long periods before he observes any signs of disintegration, and even then such signs may be of a doubtful nature. It is in fact necessary to avoid certain accessory phenomena, such as the formation of superficial crusts, which according to circumstances, may retard or accelerate the decomposition or hide its effects

More scientific and expeditious methods have been proposed, and it will be a point of importance that experiments be made on these in as many laboratories as possible.

Duration of Setting.

The use of the Vicat needle continues to be the only practical method in use for the determination of the duration of the period of setting of hydraulic cements. The appliance is one of extreme simplicity, but its readings are sometimes uncertain, especially when it is a question of determining the end of the period; besides, the readings are of a purely conventional character and do not appear always to bear a sufficiently constant relation to the duration of the setting period of the mortars of actual practice.

The discovery of more exact methods has therefore been attempted.

Methods of testing based on the measured variations in the electric resistance of mortars while hardening have not given results of interest.

Other investigations have aimed at the definition of the setting by the determination of the temperature of the mortar during its continuance. Reasonably regular curves were obtained by this method, which however were dependent on the testing conditions and corresponded with chemical phenomena the relation of which to the change of consistency called setting has not yet been quite clearly established.

The principle nature of the method to be employed may be the ascertainment of the time, reckoned from the commencement of the gauging, during which a given mortar can with impunity be further used without having to be revived by a fresh addition of water or a too violent mechanical treatment.

Mortars for Testing.

According to the country in which the strength-tests are made, the materials used for them consist, either entirely of sandy mortars, or both of mortars and of pastes gauged without sand; these pastes are more easy to define than the sandy mortars, and can be manufactured under conditions which more readily admit of comparison; but the value of the information furnished by them is a matter open to argument.

The mortars are composed of one part of cement and three parts of a so-called standard sand, the size of grain and nature of which exert an influence on the results of the tests.

Several countries have made exact definition of their standard sand and taken proper measures to ensure and control the purity and invariability of the material provided; but it has not yet proved possible to extend this system so far, that choice can be made of an international standard sand, and one of the Committees of the Association is charged with the task of preparing the way for a unification of this kind.

It has long been the custom to moisten the standard mixtures with relatively small quantities of water, so that they have the consistency of moist freshly-turned earth, and to belabour them energetically in the moulds, either by hand, with the spattle, or by machinery, according to rules so formulated as to ensure that the mortar undergoes a certain fixed amount of mechanical work. But the objection has been made to this method, that an appraisement based on the comparison of such mixtures might result in the classing of the different cements in an order that did not correspond with the relative strengths of the much softer mortars of actual practice, and in several countries some of the great administrations and technical associations have now adopted mortars of plastic consistency cast in the mould without ramming for their standard strength-tests. For the generalization of this method, the principal difficulty remaining for solution is the exact definement of the standard plastic consistency and of the method of filling the moulds. The same Committee of the International Association is entrusted with the study of this question.

In regard to the method of keeping the samples from the time of gauging till that of the breaking-test, it has remained

practically the same in spite of the investigations still actually in progress in some countries aiming at the discovery of another one, which shall allow of a better differentiation between the Portland cements property so called and various other competing products.

Strength Tests.

The two methods of testing in almost universal practice are that by tension, made on briquettes formed to a model which resembles the figure 8 and is almost the same in every country, and that by compression applied to cubes or to fragments of the briquettes. According to the country in question, preference is given to the former of these, which is the more easy of application, or to the latter, which appears to give a better differentiation of the different products

The proposal has been made, to replace the tensile tests by flexure-tests applied, either by a central load or by a uniform bending moment, to prisms of square section which are easy to define and to manufacture, and the halves of which are then available for compression tests. This method has obtained a favourable reception from the Association and has been relegated to the Committee above mentioned.

Another method of testing, which ought still to be found is that by shearing, the results of which would afford a basis for the calculation of the fraction of the cutting force which concrete could without danger be designed to support in the reinforced concrete structures; but there is no method yet known which, while free from every source of systematic error, will give the exact measure of this resistance.

Accelerated Tests.

It was formerly hoped that the work of time might be supplemented in the strength-tests by that of agents, such as heat, which might be capable of hastening the reactions to which the hardening of the hydraulic cements is due.

Numerous experiments have shown that, whatever the method employed, the strengths obtained never show any definite relation to those of the same cements when kept under the normal conditions for more and more lengthy periods, and it would appear that the idea of seeking a solution of this problem had now been almost given up.

Adherence.

Placed on the programme of the International Association r solution, the question of adherence-tests formed the subject, t the Brussels Congress of **1906**, of a general report in which was particularly set forth, on the one hand that the testing ıethods should render possible the measurement of the adherence, f each possible mortar to each possible material, and on the ther that they must admit of distinction being made between ormal adherence and tangential adherence, maximum forces ending to hinder the detachment according as the effort is exercised ormally to the plane of contact of the two materials or in the lane itself. In regard to the methods proposed for the measurement f the two kinds oı adherence, it would have been imprudent to dopt them without verification, and the reporter himself asked ıat experiments should be made in different laboratories before ıe Association declared their approval of them.

An adherence of another kind, the interest in which increases rom day to day, is that which tends to counteract the sliding f bars of metal in reinforced concrete. This is a resultant of the angential adherence which has just been defined, of the resistance pposed by the concrete to being itself sheared by superficial oughness of the reinforcing metal, and finally of the pressures xercised between the iron and the concrete as much by the lterations of volume accompanying the hardening of the latter as y the transmission of the force efforts set up in the block by the ction of external loads. This resultant, which may be called the esistance to gliding, is, however, of a very complex nature; our nowledge of the law by which it varies from one point to another f the surface of contact of the two materials is very imperfect, nd it is in fact impossible to calculate its value with absolute xactness, in spite of the numerous experiments by the aid of vhich its measurement has been attempted.

Tests on Puzzuolanas.

Normal courses of procedure are in existence in Germany, Holland, and Belgium for the reception of trass, and in Italy there re official regulations which indeed are of quite recent date, that re applicable to the puzzuolanas of that country; but no general nd uniform method for the testing of puzzuolanas, whatever their ıature and origin may be, is as yet in existence.

A Committee has been nominated by the Internationa
Association to take up this question. They have already come to
a number of conclusions and furnished several reports; the
methods proposed, however, have not been considered so far ripe
that they can be adopted without further experiments being made.
The solution of the problem is also in part subordinate to that o
the testing of hydraulic cements, properly so called, with the
complication that, the puzzuolanas not setting by themselves, it is
necessary exactly to define the normal lime which should be mixe
with them in the standard mortars. Finally the partial combinatio
of the active elements of the puzzuolanas with the lime is i
general very slow, so that the strength tests can scarcely yiel
useful information till after the lapse of a some long period of time

It would be desirable that a chemical test should be dis-covered which could quickly show the relative strengths of the various puzzuolanas; but up to the present none of those whic have been thought of have given results that are sufficiently i accord with the practical qualities occuring in the use of thes materials.

Conclusion.

To summarize the foregoing, apart from the old method retained without any modifications of importance by Committe No. 22, the Association have not yet adopted any of the testing methods of which the special Committees have made study, an these Committees have moreover considered themselves unable t formulate definite proposals in favour of this or that new method

At first view a stagnation of this kind may appear regrettable But extreme prudence is imposed on the Association in the choic of testing-methods to which they are asked to give the suppor of their authority, and it is of importance that they should no officially patronize any such which has not previously been dul checked hy a number of competent experimenters.

The part to be played by the Committees of the Associatio is precisely that of promoting the elaboration of better method than the ones previously in use, to verify these by parallel ex periences obtained in different laboratories and, if need be, t further improve them. When sufficiently developed, these method will impose themselves on technicists without further ado, and i will only remain for the Association to affix to them the stam of their official sanction.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

V[TH] CONGRESS, COPENHAGEN 1909.

XIII$_1$

THE BONDING OF LAYERS OF MORTAR AFTER DIFFERENT TIME INTERVALS.

By Professor **B. Kirsch**, Vienna.

Translated from the German by Dr. H. Borns, London.

The experiments, briefly dealt with in the following, are preliminary to a comprehensive investigation, and the results can not yet be stated with full certainty.*) They furnish some information, however, and suffice for guiding us in setting up a programme as to the mode in which this important problem could practically be investigated.

The 120 experiments so far conducted permit of drawing certain interesting conclusions, and the presentation of this communication to the Copenhagen Congress has been decided upon particularly for the reason that the method applied has proved entirely suitable.

The problem concerns the bonding of different layers of mortar which are superposed after certain intervals. The adhesion has been determined by means of tensile strength tests.

The surfaces under contact were rectangles, 200 mm (8 in.) in width and 100 mm (4 in.) in height.

Two kinds of cement, a Portland cement and a slag cement, have been examined, and in each case two mixtures with sand have been applied, the proportions of mortar to sand being 1 : 2

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*) The original report is published „Österr. Wochenschrift für den öffentl. Baudienst“, Wien 1909, Heft 5.

and 1 : 4. The periods of rest intervening between the superposition of the two layers were respectively 0, $^1/_2$, 2, 6 and 14 hours. These intervals correspond to uninterrupted work, work interrupted by the dinner interval, by half a working day, and by a full day or night. The time allowed for subsequent hardening was three months, during which the specimens were kept in a damp cellar.

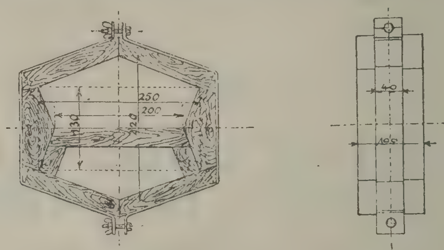

Fig. 1.

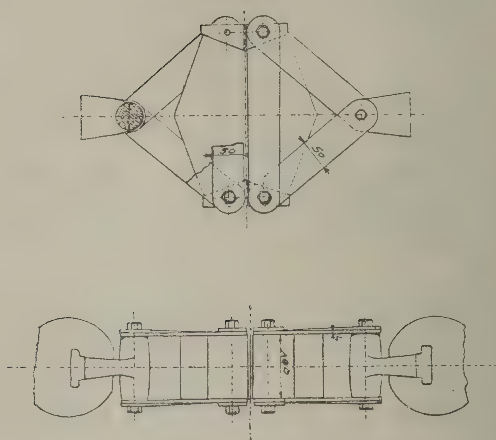

Fig. 2.

The 1 : 2 mixtures could be taken from the mould after 2 or 3 days, the 1 : 4 mixtures after 8 days. The moulds were built up of wood, lined inside with zinc to prevent absorption of water by the wood (compare fig. 1). The charge was pressed into the mould by means of pestles, but not rammed down; the contact surface was roughened a little before filling in the second half. Fig. 2 illustrates the manner in which the specimens were clamped in the machine.

The following are particulars of the cements.

	Portland-Cement	Slag-Cement
Weight per litre in kg, loose . . .	1197	908
„ „ „ „ „ firm . . .	1980	1532
Specific gravity	3,15	2,78
Setting commences after hours . . .	$4^1/_2$	$1^1/_2$
Set hard after hours	15	8
Tensile strength (kg/cm²) after 1 week	18,9	19,3
„ „ „ „ 4 weeks	24,3	23,8
Crushing strength (kg/cm²) after 1 week	272,5	252,7
„ „ „ „ 4 weeks	330,5	351,9

The volumes were constant.

The morter briquettes were prepared with a quartz sand similar to the Austrian sand.

The following table reproduces the adhesion values found, means of five tests, in kg per cm².

Interval in hours	1 : 2		1 : 4	
	Portland-Cement	Slag-Cement	Portland-Cement	Slag-Cement
0	3,82	3,20	3,96	1,56
$^1/_2$	1,24	0,86	1,20	0,49
2	1,44	0,95	1,12	0,23
6	1,05	0,63	1,59	0,20
14	1,03	0,21	1,18	0,08

Conclusions.

1. An interval of half an hour is sufficient to reduce the adhesion strength to about one-third of the concrete strength.

2. With longer intervals the adhesion diminishes further, but much more slowly than during the first half hour.

3. Slag cement appears more sensitive in this respect than Portland cement.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

XVI_1

ABSTRACT OF REPORT ON THE PRESENT STATUS OF TIMBER TESTS IN THE FOREST SERVICE, UNITED STATES DEPARTMENT OF AGRICULTURE.

By Professor **William Kendrick Hatt**, Lafayette, Ind., U. S. A.

Prefatory Note.

The timber tests of the Forest Service have an organic relation to the general problem of wood utilization, which includes wood preservation, market studies of wood-using industries, turpentining studies, wood chemistry, wood pulp and wood distillation.

Each of the six Forest Districts of the United States is served by a field laboratory, usually in cooperation with a technical school; and the work is coordinated and directed by a central laboratory in which the problems of wood utilization just mentioned are studied by individual laboratories.

These timber tests of the Forest Service were begun in 1902 under the direction of Mr. Gifford Pinchot, Forester, Forest Service, United States Department of Agriculture.

Description of the work as contemplated in 1902 will be found in the Transactions of the American Society of Civil Engineers, Vol. LI, page 67, 1903.

It should be clearly understood that these timber tests are divided into two parts: Class a). Tests on market products of actual size, in which characteristic defects occur, such as stringers, vehicle parts, railroad ties, of interest and value to engineers and manufacturers. These correspond to tests on riveted joints or

built-up structures in metal testing. Class b) includes so-called "scientific" tests of small, perfect specimens with uniform moisture-content, representing material collected from the forest, in which the strength is related to the physical structure and position in the tree. These tests are of value to the botanists and foresters. The interests of both botanists and users of timber should be served in the programme, and a broad sympathy ought to prev ail on the part of both engineer and forester with the problems of each other.

As a example, the moisture-strength law has been determined with scientific exactness by tests on small pieces; but this law can not be applied by the engineer in fixing unit stresses for design of large test pieces. In this case, tests on both small and large pieces are needed, and it would be perversity to oppose the selection of either class of material.

At the Brussels Congress, Committee 23, Section C, in its report labored under a misapprehension as to the character of the Forest Service Timber Tests, and the writer fears that the opposition to the tests of Class a) was based upon imperfect and incomplete information. For instance, the strictures of the Committee with respect to the knowledge of origin of material were not deserved. The origin of both large and small sticks is known in studies of the strength of species.

The publications of the Forest Service should shed a different light on the programme; and it is hoped that this report will present a correct account of the tests.

This paper is limited to a presentation of the conclusions derived from the various studies in which the strength of the wood is determined.

Influence of conditions of tests upon results.

In these studies, small, perfect specimens are used.

1. Speed of Test. The strength of wood varies significantly with the speed at which stress is applied, increasing more rapidly as the speed increases. The tests of the Forest Service have been standarized for speed[1]); on the basis of fiber strain per unit of time; and experimental factors obtained to adjust strength values

[1]) See Proceedings American Society for Testing Materials, Vol. 8, 1908, page 541. "The Effect of the Speed of Testing upon the Strength of Wood and the Standarization of Tests for Speed", by H. D. Tiemann.

from one speed to another. The adopted standards of fiber strain are as follows expressed in inches per inch per minute:

Large Beams	0,0007
Small Beams	0,0015
Compression parallel to grain, Small Pieces .	0,003
„ „ „ „ Large Pieces . .	0,0015

Strength of wet or green wood is much more sensitive to changes of speed than is dry wood. At the speed adopted for official tests a change in speed of 50% may ordinarily be allowed without causing a variation in strength of over 2%.

2. Temperature. Since wood is a more or less plastic substance, it is sensitive to changes of temperature. Tiemann's[1]) experiments show that soaking certain species in water at normal temperature does not affect their strength. It appears, however, that warm water has a marked weakening effect. The extreme condition is when wood is made pliable by boiling. Some woods are no doubt more sensitive than others to the effect of temperature of the water in which they are immersed. In recent tests, made in winter weather, on red oak (Quercus Rubra) ties, at Purdue University, ties taken from the temperature of the storehouse (about 25° F.) were from 9 to 17 per cent stronger than those tested at the temperature of the laboratory (about 70° F.). Probably this marked difference in strength is to be found only in case of green or wet wood. The rupture-work is not affected to the degree of the ultimate strength. Hickory seems specially sensitive to change of temperature. It is concluded that the ordinary temperature variations of the air of a laboratory are not important, but that the temperature of the storehouse may render it necessary to warm the wood. In fact, the effect of a given factor on the strength of timber, or differences of strength of two species, may, at times, be entirely masked by variations of temperature of timber at the time of test.

3. Moisture. The effect of moisture on the strength of wood has been thoroughly investigated by Tiemann[2]). His material was

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[1]) Bulletin 70. Forest Service, 1906. "Effect of Moisture on the Strength and Stiffness of Wood", by H. D. Tiemann.

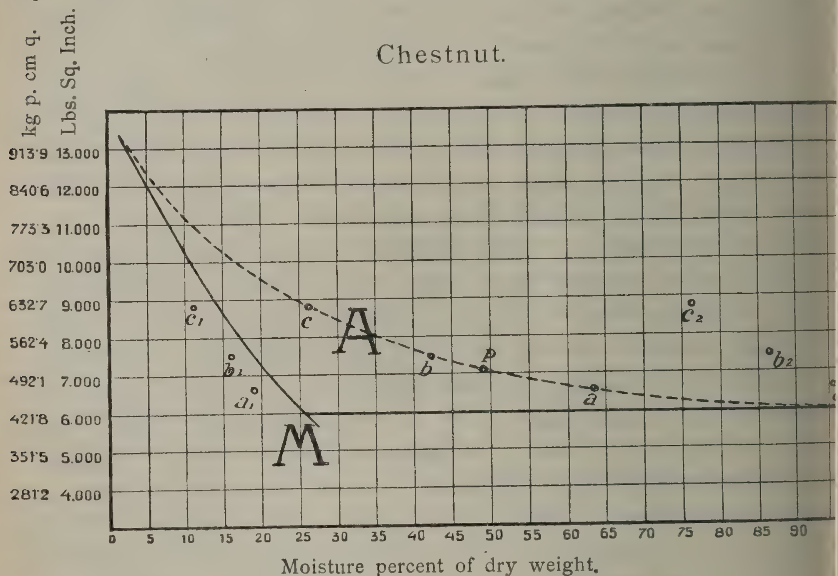
[2]) Bulletin 70. Forest Service, 1906. "Effect of Moisture on the Strength and Stiffness of Wood", by H. D. Tiemann.

Circular 108, Forest Service, 1907. „The Strength of Wood as influenced by Moisture", by H. D. Tiemann.

small test-pieces uniform in moisture content throughout the cross-section; and he determined the distinct "fiber-saturation" point, above which increased moisture content did not affect the strength of timber, and below which there was an increase of strength. Previous experiments, yielding a continuous moistre-strength law, were apparently made with "case-hardened material." See Fig. 1.

Modulus of rupture.

Fig. 1.



Effect of casehardening upon the Form of the Moisture-Strength Curve for Ben(

A = Case hardened pieces. M = Fiber saturation Point.

Relation of tests.

The relation between the strength under various kinds of tests, such as shear, bending, etc., and compression parallel to the grain, have not been determined yet by an analysis of the data. It is doubtful if any one test can be used to predict the strength of the material under other forms of tests when conditions vary with respect to previous heat treatment, moisture drying, or preservative treatment. For instance, brittleness induced by overheating is evident in impact tests, but this will not necessarily be evident from the compression test parallel to the grain

An investigation of the effect of speed of test is a part of the general study of behavior of wood under three conditions of loading:

a) dead or constant load,

b) ordinary static test with increasing load,

c) impact test.

a) Dead load tests exhibit the plasticity of wood. Nearly all deformations increase with duration of load, but the deformed beams subsequently tested show no loss of ultimate strength. Deflection brought about by humid atmosphere is not recovered subsequent drying. The question is often asked: "What per cent of the load, as determined by the ordinary static test, will break a beam if left on indefinitely?" This has no answer.

c) Under impact loading, wood will submit to greater elastic deformation than under the ordinary static tests. Impact bending tests show elastic deformations largely in excess of those experienced under static load. The impact test is made under increasing height of drop.[1] The order of resistance of air-dry woods at the ultimate failure strength, so far obtained, is as follows:

Hickory, Longleaf Pine, Douglas Fir, Loblolly Pine, Chestnut, Spruce, Yellow Poplar, Western Yellow Pine, Western Hemlock, Sugar Pine and Coast Redwood.

d) Abrasion Test. The abrasion test is under study.[2] Wood is worn by sand-paper in the Dorrey Machine.

Influence of treatment previous to test.

a) Drying in Hot Air, Steam, Saturated Steam, etc. A research is under way to investigate the safe limits and the most advantageous conditions for the commercial processes of drying wood. The immediate strength after drying is of course usually greater because of the lessened moisture content. It is now apparent, however, that all processes of drying wood, even air-drying, are attended with weakening of structure, so that when the dried wood is resoaked there is a loss in strength of 10%, and generally more. The drying of white ash (Fraxinus americana),

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1) Circular 38, Revised, Forest Service. "Instructions to Engineers in Timber Tests", by W. K. Hatt.

2) See American Society for Testing Materials, Vol. 7, 1907. "Purduc University Impact Testing Machine", by W. K. Hatt.

for instance, at 145° F. in either dry air or exhausted steam, or in superheated steam at 312°, caused no significant loss in strength in the air dry condition, but the resoaked wood was considerably weaker than the green wood. Under 20 to 30 pounds of steam applied during 1 to 4 hours, pine and ash suffer but little loss in static strength after the moisture from the steam is removed by air drying. At higher steam pressures (above 50 lbs.), large and permanent losses result. An equal amount of dry heat is less injurious to wood than moist air or saturated vapor, whenever the temperature exceeds 212° F. The hygroscopicity of the wood in the air-dry condition is reduced by the process of drying in steam, dry-air or saturated steam.

The impact resistance of wood, which has been dried by the various processes in this study, is yet to be determined. Comparisons must be based on both static and impact tests. A preliminary investigation showed that a certain treatment had not affected the strength of pine and ash when judged by the static compression tests parallel to the grain. Under an impact test in bending, the conifers were not affected by the heat treatment. However, the white ash (Fraxinus Americana) showed 50% reduction in impact resistance.

The results from the Drying-Strength Study are not sufficiently advanced to allow complete conclusions.

b) Treatment with Preservatives. Tests at the Louisiana Purchase Exposition[1]) established the safe limit of steaming for seasoned loblolly pine to be 50 lbs. applied for 4 hours, or 20 lbs. applied for 6 hours. Burnettized loblolly pine ties exhibited some degree of brittleness under impact test. Creosote appeared to act upon the strength in the same way as water. It retards the seasoning of timber, with beneficial results to its physical condition. Present evidence points to steaming, or effect of heat in preliminary seasoning, as the only dangerous element of the treating process. The proper limits of heat should be determined for different species of timber.

In the case of bridge timbers, of coniferous species, of large size, incomplete evidence indicates that the desired penetration of

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[1]) Circular 39, Forest Service, "Experiments on the Strength of Treated Timber", by W. K. Hatt.

creosote can only be obtained by cylinder processes that reduce the strength of the timber. The unit stresses used in the design of creosote structures should, therefore, in these cases, be decreased below standards established for natural wood.

Improvement of specifications.

It is a well-known fact that many clauses in specifications for structural timbers are the result of tradition and not predicated upon fact. It has been determined by the Forest Service that the red and yellow varieties of Douglas fir (Pseudotsuga Taxifolia), used for bridge stringers, are of equal value, and that both "red" hickory and "white" hickory are of equal value for wagon parts.[1]) The recently revised specifications of the National Hickory Association are based on these tests. Tests of loblolly pine (Pinus Taeda), Douglas fir (Pseudotsuga Taxifolia), and Shortleaf pine (Pinus Echinata) beams determine the location of knots that will not affect the strength of stringers, and the results have been used in printed specifications of the railway organizations and the Yellow Pine Manufacturers Association.[2])

The test pieces are full size.

In these cases, observations are made to fix proper specifications of limit of growth, with respect to rings per inch, or per cent of summer wood within which suitable material may be found.

Unit stresses for design.

The relation of strength of large sticks, involving defects, to small and perfect pieces, taken from the parent beam, is reported in Circular 115, Forest Service. The strength of large and small sizes is not a question of geometrical magnitude, but of the existence of defects in the large sticks, such as knots, shakes, checks and the presence of inferior growth.

Study has been given to the failure of large beams under longitudinal shear. It is apparent that, in the case of large beams of seasoned timber, the failure is due to longitudinal shear rather

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[1]) Circular 142, Forest Service, "Tests of Vehicle and Implement Woods", by H. B. Holroyd and H. S. Betts.

[2]) Circular 115. Forest Service, "Second Progress Report on the Strength of Structural Timber", by W. K. Hatt.

than to bending. In green beams, also, this form of failure is frequent. Therefore, shearing stresses should be taken account of in the design. The result of later tests confirm the early results that the strength of large pieces is not increased by subsequent seasoning, except in case of select grades. In other words, unit stresses for design should usually be based upon strength of green timber. Tests on the following species are about complete in large sizes for structural purposes:

Loblolly Pine (Pinus Taeda).
Shortleaf Pine (Pinus Echinata).
Norway Pine (Pinus Resinosa).
Tamarack (Larix Laricina).
Western Hemlock (Tsuga Heterophylla).
Douglas Fir (Pseudotsuga Taxifolia).
Western Larch (Larix Occidentalis).

No doubt exists as to the origin and the species in the case of this structural timber. The observations on large timbers include, not only the strength, but also the distribution of moisture, the shrinkage from the green to the air-dry state, and the weight. In all cases small test-pieces are cut from the parent sticks for minor tests.

Timber from national forests.

It is the policy of the Forest Service to dispose of the increment from the National Forests, and it is necessary to study the wood product and overcome obstacles to the sale that might result from prejudice. The value of common cheap timbers is determined, and their use promoted. Tests along this line include fire-killed timber, which, in small sizes, is shown to be as strong and as valuable as live timber. In large sizes, the checks which develop in the standing tree are detrimental. These timber tests are to be regarded as a necessary instrument of Forest management. Small test pieces are generally used.

New species and substitutes.

The eucalypts of California and the South have been tested. Some species are among the strongest of our woods. The quality of

the various species differs greatly, varying in kiln dry state from 25.000 pounds per sq. in. to 13.000 pounds per sq. in. in modulus of rupture.[1]) Tests have been completed on tan-bark oak, which formerly was left stripped of its bark in the woods.

General studies of species.

Tests of red gum are completed.[2]) Tests of various species of hickory collected from various site conditions have been made and the report completed. These latter tests established relations between rate of growth and strength, locality and strength, and species and strength. It appears that the most fundamental factor governing the strength of wood of any species is the specific gravity, or, in the conifers, per cent of summer wood.

Technical Problems. The study of track fastenings, including common and screw spikes, and tie plates, and the relation of these to the strength of ties, is in progress. Laboratory tests are supplemented by service tests in tracks of railroads under operation.

Technique of tests and the organization of the laboratory work.

The methods and records and organization are now well developed. The results of experience for the past six years are given in the Circular 38 (Revised) Forest Service U. S. Dep. of Agriculture entitled "Instruction to Engineers in Timber Tests". Recently a department of microscopic examination of wood has been added to study manner of failures in the tissues, changes in structure resulting from heat treatment, location of preservative fluids and allied problems.

Conclusions.

The restriction of space has made is necessary to state in the most general way the present status of the timber tests and

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[1]) Trade Bulletin.

[2]) Bulletin No 58, Forest Service, "The Red Gum", by Alfred K. Chittenden.

will not allow quotations of numerical results. As an evidence of the activity of timber tests, the statement that 44,000 tests have been performed since 1902 will be of interest. A list of complete and incomplete studies that have been under way since 1902 in the Forest Service Timber Tests will be submitted.

The problems and activities in the line of wood preservation and their studies will not be dealt with since they are related in only a general way to the Department of Timber Tests.

INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

III1

REPORT ON IMPACT TESTS OF METALS.

Official report by **G. Charpy,** Montluçon.

Translated from the French by Dr. H. Borns, London.

The use of impact methods for testing metals, which had een applied in diverse empirical forms, has of late and in con-equence of the introduction of notched-bar tests been the subject f many researches and lively discussions. The International Con-ress held at Budapest in 1901 had charged Commission 22 with e examination of fragility tests and with defining the experimental onditions to be adopted for these tests. The official Report, drawn p by Mr. Sauvage for the Brussels Congress of 1906, gave résumé of the numerous memoirs published on the question p to the time and of those presented to the Congress. The Report d to a prolonged discussion, apparently not to the advantage of e new method. For the Congress rejected the resolution deman-ing that the use of notched-bar tests should be generalised, and ontented itself with expressing the opinion that these tests were „susceptible" of furnishing interesting information.

This condemnation has not been passed without calling forth n appeal. It is impossible not to recognise that the application of otched-bar impact tests has taken a considerable development ince 1906, that these tests have been employed on all sides for e purpose of study, and that they have even been introduced to some official specifications. The development has, however, een hampered by the failure of the Brussels Congress to supply solution to the question that had been put to it, viz, to define e experimental conditions to be adopted. The German Association

for Methods of Testing Materials without delay appointed in 190
a commission consisting of Professors Martens and Stribeck
Dr. Lasche and Dr. Ehrensberger (one of the managers o
Messrs. Krupp) for this object. The report of this commission
drawn up by Dr. Ehrensberger, which recommended the use o
notched-bar impact tests, was adopted by the general meeting o
the German Association held in Berlin on October 5, 1907.[1])

This is a very important fact to which it will be impossibl
not to draw attention during the discussions that are to take plac
at Copenhagen. The reporter, who has been particularly glad t
see many of his views adopted by the eminent members of thi
German commission, does not consider himself qualified to defen
the Commission's conclusion. He will confine himself, therefor
for the purpose of facilitating the discussion, to grouping a certai
number of facts and observations respecting the various point
which have to be distinguished in the problems of impact tests
bearing in mind the views which were uttered at Brussels. He wi
also deal with the recent literature on the subject. I quote in par
ticular, and addition to Mr. Ehrensberger's report, the "Réflexion
au sujet des Méthodes d'Essai des pièces métalliques et du Con
grès de Bruxelles de 1906", published by Mr. Simonot, princip
engineer du Génie Maritime, in the Bulletin de la Société de l'In
dustrie Minérale (1907, No. I) and discussed at the Meeting o
June 1, 1907, of the "Réunion des Membres Français et Belge
de l'Association Internationale pour l'Essai de Matériaux". Further
the articles by Mr. Pierre Breuil on novel methods of testing
metals, published in the Revue de Mécanique 1908; finally th
memoirs by Messrs. Stanton and Bairstow on the resistance o
metals to impact, and of Mr. Harbord on "Different Methods o
Impact Testing on Notched Bars", discussed by the Institution o
Mechanical Engineers in its general meeting of November 20, 190

I. On the Use and the Sense of the Term "Fragility".

Impact tests and especially impact-bending tests on notche
bars have generally been regarded as a means of determining th
fragility of metals. But people have not sufficiently preoccupie
themselves with exactly defining the meaning of this term, whic

[1]) Stahl u. Eisen, 1907, No. 50 and 51; Revue de Métallurgie, April 190

certainly has been abused in so far, as some authors simply state that certain metals are fragile and others not fragile, whilst most of the devices applied aim at arriving at some universal value. If it is true, as Captain Duguet[1]) says, that "if words do not correspond to a well-defined idea, they can call forth different ideas, and that this is the most fertile source of our errors", it does not appear useless to inquire into this question before speaking of impact tests.

The French Commission on methods of testing materials of construction was struck from the very beginning of its deliberations with the necessity of precisely defining the signification of the technical terms used in the practice of testing, and it nominated a sub-commission for technical Terminology. We take the following lines from this report drawn up by Mr. Gandillot.

"Fragility. Fragility is the property of being easy to break (frangere). One might accordingly, for each mode of testing, distinguish between a static fragility and a dynamic fragility or an impact fragility, which would respectively signify: the properyt of possessing a feeble static resistance or a feeble dynamic resistance.

But the term fragility calls forth above all the idea of this second property.

Mr. Auerbach has proposed to characterise fragility as the difference between the resistance (breaking load per mm^2) and the elastic resistance (elastic load limit per mm^2) or by some other function involving this difference as factor.

Mr. Considère has proposed, in 1889, to measure fragility by the ratio of these two resistances.

It must be pointed out that what constitutes the fragility of a material, is not, strictly speaking, the small difference between these two resistance values, but rather the slight difference between the corresponding deformations, the feeble deformability by virtue of which the material does little resistance work before breaking.

However that be, it does not appear necessary to search for a special measure of fragility, because whatever the stand-

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[1]) Duguet — Limite d'élasticité et résistance à la rupture. Vol. II. (with preface). Paris, 1885.

point one takes, and whatever the cause which produces it, fragility is the essence of bodies, for which the resistance, or the deformability or the dynamic resistances, are measured by low figures."

The same order of ideas appears to have been adopted by Mr. Henri le Chatelier in the Introduction which he has written to the "Contribution à l'étude de la fragilité", published by the Société d'Encouragement in 1904.

"One has always known," he says, "that certain metals are regularly fragile, that is to say, that they always break, without practically undergoing any extension, and that consequently their rupture requires only a very small expenditure of work."

Mr. Considère says on the same subject:

"The name of fragility has been given to the property which most hard bodies possess of breaking easily, in undergoing little or no deformation and in producing only a small resistance work."

And elsewhere:

"One qualifies, and will no doubt continue to qualify, as fragile, bodies which break easily under certain conditions and while suffering little or no deformation and in producing only little resistance work, whatever be the causes of the rupture."

Thus numerous authors regard the notion of fragility without connecting it with the influence of the shock. In other instances, on the contrary, the idea that fragility must be referred to dynamic tests is clearly evident. Thus Mr. Barba writes: "The fragility of a metal may in everyday language be defined: the facility with which a metal breaks under a feeble destructive stress when this stress is the result of an impact. In a memoir on fragility by Mr. Brosser, Engineer in chief of the Génie maritime we read: "Fragility is commonly defined as the tendency of bodies to break under shock." A little more complicated is the conception of Mr. Vanderheym who says: "I propose as definition of the property known as fragility, for a metal produced by fusion, the predisposition which the crystals of which the metal is composed show to separate under the application of a sudden stress."

In order to bring these various definitions into accord or to choose between them, we are naturally led back to the idea adopted by Mr. Gaudillot and to a separate consideration of fragility for each kind of strain and for each mode of application of the stress. In every case the classification of the metals as to

their fragility should be effected either according to the work absorbed in fracture, or according to the deformation before the fracture. All the authorities quoted agree in regarding these two quantities as interconnected. Yet, in order to arrive at numerical values, we have to choose between them. If we refer to practical applications, it seems certain that the work done in fracture has more importance. All the same the deformation before fracture would be more easily determined and would consequently facilitate comparisons in a great number of cases.

The first question which we have to ask ourselves is, how many distinct fragilities there are. To answer it, we shall have to study successively, both as to the work done in fracture and as to the deformation before fracture, the tests on tension by gradual stress and by impact, bending by gradual stress and by impact, compression by gradual stress and by impact, not to speak of more than the most customary deformation tests.

The different quantities are not in any precise fashion directly connected with any specific property of the metal such as its fragility. It appears hence prudent, until further progress in our knowledge of metals will have been made, to avoid terms of this kind and to confine ourselves to state as clearly as possible the quantities resulting from each test, without wishing to go beyond the experiment.

The German Commission appears to have adopted the same point of view in proposing to designate as tenacity of notched bars (Kerbzähigkeit) the quality of the metal defined by the notched-bar impact test (Kerbschlagprobe), and as specific work done in fracture (spezifische Schlagarbeit) the numerical value of the test referred to the square centimetre of the broken cross section. In a paper presented to the Congress of Budapest, in 1901, we had proposed the name of resilience for this latter quantity.

II. Which is the Relation between the Tests producing the same Deformations both by Impact and by Gradual Application?

The idea which has induced us to submit metals to impact tests incontestably implies the admission that there exists a marked difference between two tests which would produce the same strain by impact and by gradually applied stress The fact that impact

tests are universally adopted (generally in the form of bending tests on plane, not-notched) bars, and that considerable importance is attached to their results would tend to indicate that the correctness of the idea to which attention was drawn above had clearly been demonstrated by experiments. When we examine the comparative tests of this type, however, we find on the contrary that the experimenters most generally believe in a slight difference between the effects of dynamic and of static stresses. It will not be useless to quote some of the opinions concerning this point.

Captain Duguet writes: "The effect (of the duration of the stress) is very marked, especially during the period of great deformations; that would in itself suffice to render any too detailed investigation of the phenomena illusory. But we must not exaggerate the importance of this point. The extreme deformations are, in the case of soft steel submitted to bending, very sensibly the same, whether they be produced slowly by hydraulic pressure or by the impact of a tup."

In his treatise on material testing Professor Martens points out that, according to the experiments of Kick, the velocity of fall has only an insignificant influence on the magnitude of the deformation in impact bending tests. As regards tensile strength tests Professor Martens concludes: "From the impact tension tests so far conducted in the Charlottenburg Laboratory, I have acquired the conviction that the deformations are produced exactly as by slow tension. In tension tests by means of several blows, we find often that the elongation was greater than in the slow tension tests."

M. Lebasteur (Annales des Ponts et Chaussées, 1890) had likewise arrived at the following conclusions:

"1. The elongations observed in the fracture of bars under high-drop impact tests are nearly identical with the elongations of similar bars under slow tension.

2. The appearances of the broken sections are absolutely the same in the two cases.

3. The total intensities of the blows necessary to break bars under high-drop impacts are proportional to the dynamic resistance to rupture (as determined from the area the curve of slow tensile stress)", and further on Mr. Lebasteur added that "the dynamic resistance to rupture measures the strengts of metals equally well for dynamic as for static stresses".

Mr. Hatt has described in the Proceedings of the American Society for Testing Materials, 1904, a long series of experiments made with a hammer, very ingeniously disposed so as to record the velocities from which the work done could be deduced. Mr. Hatt concludes that, for steels, there is little difference in the total elongation and the unit work done in fracture, whether this fracture be brought about in the space of 10 minutes or of a hundredth of a second.

Mr. Breuil, at the end of a long paper published by the Iron and Steel Institute, writes: "This is sufficient to admit that the curve of sudden bending under the influence of a blow would be almost identical with the curve obtained by slow bending", and further on: "The most important final conclusion from these tests is that a slow stress produces the same effect as a sudden stress of metals (at least of those which the author has examined)."

We have ourselves pointed out in several notes, and notably in a contribution presented to the Brussels Congress, that comparative notched-bar impact tests and gradual stress tests gave values which differed little in absolute values and which led to the same relative classification of a series of metals.

We might quote further experimental data pointing to small differences between dynamic and static tests. Different results have however, been obtained by Mr. Considère. In submitting iron wires to impact tension tests at different velocities, Mr. Considère has found that, "when the velocity of the impact is progressively increased above the minimum necessary to produce fracture at a single blow, the resistance of the breaking metal increases at first at the same time as the velocity, finally exceeding the static resistance by 50 or 100 per cent, and the elongation during fracture remains approximately constant."

"When afterwards the rapidity of the impact attains a certain limit, a sudden and absolute change of the mechanical properties takes place in the metal, a change which agrees with the notion of fragility. Rupture ensues under a very small elongation, and the resistance is less than a third of that which was observed with less violent blows. The work done in fracture hence is suddenly reduced in an enormous ratio; in one example, taken at random, it fell from 20 to 1."

These phenomena have again been observed in wire tests made by Mr. André Le Chatelier. The explanation given by this engineer ascribes the diminution of the strength to a kind of vibratory phenomenon which tends to localise the deformation. The elongation consequently affects a shorter length of the wire and seems to be reduced for this reason; if the elongation were measured, however, not on the total length, but on the different elementary portions, we would find that in the parts adjoining the fracture, it is equally great, whichever the rapidity of the blow. The phenomena would then not be assimilable to fragility, and the great length of the wire by contrast with its diameter would be the only cause of these fluctuations which experimenters on short test pieces have not observed.

As it may be objected, however, that the latter experimenters did not apply sufficiently great drop velocities, we have thought it would be useful to make some impact tests on bars at much greater height of fall than those with wich Messrs. Considère and A. Le Chatelier had observed a diminution of the elongation.

Making use of the chimney of some works we have been able to try heights of fall up to 47 m (154 ft.). Even with these heights we have not confirmed the phenomenon wich M. Considère described. The particulars of these tests will be published on another occasion. We only reproduce the results concerning two soft steels They yielded values very similar to the tensile strength tests, and very different figures from the impact bending tests; the similarity observed in the slow tension tests has been maintained on the impact tension tests.

The results obtained with the two steels which we designate by the letters A and B are tabulated below.

The tensile strengths tests were made with bars of 13·8 mm diameter and 100 mm length between gauge points. The slow tension tests were made on a machine giving an elongation of about 0·1 mm per second, and the work done in fracture was deduced by means of the planimeter from the diagram recorded by the machine. For the impact tests a tup was made use of into the upper portion of which one of the heads of the bar was screwed and which was allowed to fall from a height of 47 m upon an annular base, this base stopped the cross bar into which the other end of the bar was screwed.

After having broken the specimen, the tup continued its fall and crushed three cylinders of copper from whose flattening the residual energy and hence the work absorbed in fracture could approximately be estimated. The mean elongation velocity in these tests was a little more than 20 m per second, 200.000 times greater, therefore, than in the preceding test.

Slow Tension

	Elastic Limit	Maximum	Elongation per cent	Contraction of area $\frac{s-s'}{s}$	Work done in fracture
A	30·1 kg	42·1 kg	32·0	67·2	179·5 kgm
B	30·0 „	44·1 „	31·5	65·6	185·0 „

Impact Test

		Elongation per cent	Contraction of area $\frac{s-s'}{s}$	Work done in fracture
A	first test	40·0	70·4	215 kgm
	second „	34·1	63·8	195 „
B	first test	36·0	65·5	190 „
	second „	40·1	69·0	200 „

The values of the impact tests for the work done in fracture can only be regarded as approximate, as the method did not allow of precise measurements. We may, however, assume that the work done in this case was much greater than in the slow tension tests. That is what M. Considère had observed for fine wires at small velocities, and what we find confirmed, for relatively short bars ad considerable velocities.

The two metals employed, practically identical so far as the breaking test is concerned, differed yet much in the bending tests of notched bars which prove that the B steel is distinctly fragile. In fact, when bars of 30 by 30 by 160 mm, notched halt through by a cut rounded off to a radius of 3 mm, were submitted to pendulum hammer tests, the metal A yielded the value of about 200 kgm for work done in fracture (44 kgm/cm^2), the bar not being quite broken although bent through 60^0; while the metal B absorbed a total of 13·5 kgm (3 kgm/cm^2), and the two portions of the broken bar formed an angle of about 175^0. We have further submitted these notched bars to other bending tests by slow stress, not by impact, on a testing machine, in which the work done in fracture was deduced with the aid of the planimeter from the stress-strain diagram. We observed again a difference between the two steels, less accentuated, however, than in the impact tests. The metal A, bent to 60^0 without breaking, had absorbed a work of 145 kgm; the metal B broke when bent to an angle of 140^0, having absorbed about 55 kgm.

In these experiments, therefore, a considerable increase in the rapidity of the tension has not produced any diminution in the elongation, nor in the work done in fracture, although the one metal was susceptible of breaking under slight deformation and small energy in the notched-bar bending tests.

We have tested other metals in the same way, and we have never observed any discontinuity when exceeding a certain velocity of the impact.

It would in fact appear to be in this form that the problem should more logically be put. The expression "impact test" generally calls forth the idea of instantaneous fracture, which cannot be realised, at least not with malleable metals.

The impact produces in reality a deformation, which is more or less rapid, but never instantaneous, and which has the inconvenient peculiarity that it takes place at a variable rate. It can even happen in the case of a metal which requires an amount of work done only lightly inferior to the work which the tup could accomplish, that the deformation begins at a pretty rapid rate and continues at a very much reduced rate. This point introduces another difficulty into the interpretation of the results which must not be overlooked. The problem, which was outlined at the end of

he preceding section, and the questions placed at the head of this ection, must still be generalised. We cannot content ourselves vith successively studying the deformations resulting from gradually pplied stress and from impact. We must study the deformations roduced by velocities ranging from almost zero value up to very igh figures. The questions which suggest themselves are to deermine, what relation exists between the tests which yield the ame deformation with different velocities, and whether there are netals, for which this relation displays a discontinuity for certain elocity values. This is one of the most complex and delicate roblems which is far from being solved. We know that the velocity of deformation has a notable influence on the results of tests nade on ordinary testing machines. This influence becomes more ronounced when the velocity is further augmented; is there a udden variation which sets in at a certain velocity? It is not mpossible that the phenomenon takes place at very high velocities vhich might, in certain tests, be attained locally by virtue of ibratory effects. Yet, according to the experiments just tabulated, t appears most probable that such a discontinuity is not produced, s long as the velocity remains within the limits which we can ttain with the fall of a tup and which correspond also to the elocities of the most rapidly acting machines.

III. Which Conditions should Impact Tests satisfy?

The considerations just submitted do not at all aim at pleading he inutility of impact tests. Their final conclusion bears a hypohetical character, and as it is not impossible, that certain metals nay display discontinuity at relatively small velocities, which experiments so far made have not yet brought out, it will always e more prudent to make sure by a direct test, before employing metal, that it is not especially sensitive to the action of blows. Moreover, impact tests permit, given suitable devices, of determining ertain quantities more easily than by gradually applied stress. This holds for instance, in the case of the work done in fracture. The apparatus disposed in such a manner as to measure the energy remaining in the hammer after fracture, gives this value directly, while the use of a testing machine for slow tension depends on stress-strain diagrams, whose areas have to be evalunted

by the aid of the planimeter which is a somewhat tedious an delicate operation.

Impact tests must, however, not be conducted in the purel arbitrary fashion in which they are usually entered in actua specifications. A rational test would produce fracture of a test-ba at a practically constant velocity and would measure the stresse which come into play during the different periods of the test. Tha would necessitate more delicate methods, very different from thos actually employed, which practically rely exclusively on the de termination of the change in the velocity of the tup.[1]) It is, there fore, useless to propose to render this velocity fairly constant, bu we can attempt not to let it undergo multiple and considerabl variations. As a consequence we should abandon the method whicl estimates the work done in fracture from the required number o blows.[2])

The fracture of a test-bar by a single impact of the tup effected by means of an apparatus which permits of estimatin the work done in some way, would incontestably yield mor interesting results more easily interpreted. Nevertheless, as long a this interpretation is not quite within the reach of the state of ou knowledge, it is indispensable, in order to ensure comparabl results, always to work under the same conditions, that is to say to use a tup of definite agreed weight falling from a fixed heigh on test-bars always of the same shape and dimensions. Test conducted under other conditions are certainly not to be neglected but they will serve another purpose. Their object will be exactl to determine the laws of the more or less rapid deformations an thus to render possible comparison under different test condition such as we cannot effect at present. As long as that remains so it will be wise to compare with one another only tests conducte under rigorously identical conditions.

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[1]) We should, however, draw attention to the interesting method o Messrs. Perot and H. Michel-Lévy, presented to the meeting of the Frencl and Belgian members of the Association Internationale des Methodes d'Essai o February 27, 1904.

[2]) We speak here only of the tests in which several blows are applied t produce fracture, and not of the methods in which very many small blows ar applied, such for instance as the method of Messrs. Stanton and Bairstow which are based on a different principle and which present considerable interest

On which mode of testing shall we rely, tension, compression, bending, etc.? In principle all these methods offer interest, and none of them should be neglected in our endeavours of enlarging our knowledge of the properties of solids. In practice we shall necessarily have to limit ourselves and to decide on one particular test which will be suitable in most cases. At present we shall hardly hesitate to consider any other but tensile strength and bending tests. In each of these cases we shall have to choose between test-bars of uniform cross-section over a greater or smaller length, on the one hand, and test-bars of partly reduced section or notched bars on the other hand. All the other modes of testing that may be imagined — and their number is very great — do not appear so far to have been adapted to practical needs, and they may provisorily be disregarded.

We have, therefore, to consider four methods of testing: impact tension on plane cylindrical rods, impact tension on notched bars, bending by impact of prismatic test pieces, bending by impact of notched bars.

It does not appear possible to state in general, that any one of these methods, considered separately, offers more interest than the others. In making a selection it will be advisable to approach, on the one hand, other tests to wich the metals might be submitted and, on the other hand, the conditions under which the metal will be used.

Regarded from this double point of view the numerous memoirs recently published seem to lead to the conclusion, that the slow tension test which are almost universally applied in the first instance and which seem to define a metal, so to say, are more efficaciously supplemented by the notched-bar bending tests than by any other tests. Some of the arguments which seem to support this opinion are summed up in the following sections.

IV. Do Notched-Bar Impact Tests of Metals furnish Information which other Tests do not give?

Fairly numerous experimental data seem to answer this question in the affirmative. It has notably been observed in repeated instances that two metals which yielded identical breaking strengths and which could both be bent over a mandrel without cracking, would break in a notched-bar impact test under very

different deformations and very different energies. It might be objected that this discordance is only apparent, that we deal in every test only with a small number of factors, and that they are not the same which are encountered in different tests. Yet when we attentively examine the data published under this head, we find that the apparent discrepancy between the bending tests of notched bars and of the quantities generally determined in tensile strength tests, the elastic limit, the breaking strength and the elongation, still persists when we study, in addition, the proportional elongation, the contraction of area, and the work done in fracture. It appears indeed, as if these tests involved two different modes of fracture, and this conlusion is strengthened, when we attempt to picture to ourselves, how the fracture is propagated through the micrographic elements of the metal. At the Budapest Congress Mr. Henri Le Chatelier had already remarked that certain results furnished by notched bars could be interpreted by admitting that the fracture of the same steel might, according to circumstances, take place across the network of perlite or across the grains of ferrite. This ingenious suggestion of intracellular and intercellular fractures, which has clearly been verified in certain alloys, does not seem to conform to the case of soft steels. The examination of steel fractures appears to demonstrate that intracellular and intercellular separations occur by the side of one another, that the line of fracture, arriving at a grain of ferrite, would be able either to traverse it along a cleavage, or to circumvent it following a joint, according to the inclination of the different lines. We should therefore suggest to modify this interpretation in the following manner: When a plastic metal is subjected to a general strain, the different microscopic elements are modified simultaneously but to an unequal degree, until the one of the two attains its limit of deformation and is broken. The fracture is then propagated through the interior of the metal according to laws depending on the special conditions of the case. One understands that rather different results will ensue in accordance with the more or less accentuated differences between the diverse elements. In examining various mechanical tests from this point of view we recognise that in tensile strength tests all the elements will be deformed simultaneously and approximately in the same manner, and that the fractures will ensue between

elements which have been worked to an equal degree. In notched-bar bending tests, on the other side, the element which forms the bottom of the notch will much more rapidly be strained than all the others and will already be broken, when the others are scarcely strained yet. The fracture will hence be propagated through elements which are little worked. We understand that the modes of fracture are very different in the two cases, and that the resulting strength values will not present any direct relation. Other tests will probably yield intermediate values. We have not sufficient data regarding this point; but it would appear that the tension tests and the bending tests of notched-bars are the most dissimilar.

If this interpretation is correct, we should expect that the tension tests of notched-bars should not agree much better than the tensile tests of plane cylindrical rods agree with the notched-bar bending tests. The notched-bar tension tests should correspond to the last period of the tensile tests of cylindrical rods.

We have made experiments in this sense and prepared specimens of the same metals for ordinary tension tests, notched-bar tension tests and notched-bar bending tests.

The results of the experiments with four metals are tabulated below. The metals A and B are the same which were used for the previously mentioned experiments (Section II).

Traction tests on cylindrical rods							Notched-bar impact test: cylindrical, Tension	Notched-bar impact test: prismatic, Bending
Metal	Elastic limit	Maximum resistance	Elongation	Contraction of area	Total work done in Fracture	Work done in Contraction	Total work done in Fracture	Work done in Fracture per cm²
A	30·1	42·1	32·0	67·2	179·5 kgm	62 kgm	84·49 kgm	44 kgm
B	30·0	44·1	32·0	65·6	185 „	40 „	77·57 „	2·7 „
C	32·1	45·1	31·0	67·0	192·2 „	37 „	74·04 „	20·2 „
D	36·1	53·5	25	51·8	180·5 „	35 „	63·18 „	18·7 „

In the tension tests of cylindrical bars we have determined the total work done in fracture by planimetric measurement of the diagram, and we have also attempted to determine the work done from the moment where contraction sets in, supposing that this moment is that of maximum resistance. In our opinion it is this last mentioned quantity which should be compared to the work done in fracture in the case of a notched-bar tension test. The notched-bar tension test was carried out with the aid of a pendulum hammer directly yielding the work absorbed; it was applied to bars provided with a circular notch of the shape of a truncated triangle (profile of a screw thread on the international system.)

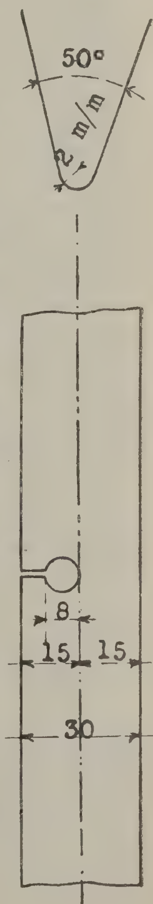
We see that the values of the work done in fracture in the notched-bar impact tests arrange themselves in the same order as the work absorbed by contraction, and that they do not lead to results which differ much from those obtained with plane cylindrical rods, whose coefficients, as we have pointed out in section II, are not much affected when we apply impact tests instead of slow tension tests. On the contrary the bending experiments with notched-bars bring out striking differences between the different metals which do not become apparent on any tension tests, and this is particularly noticeable in the case of the steels A and B. The discrepancy cannot be attributed to any irregularity of the test. For it re-occurs in several specimens, and it can moreover be produced at will by submitting the metals to suitable thermal treatment. The metal B shows coarse grains of ferrite. When this texture has by heat been changed to fine grains, the work done in fracture in the notched-bar bending tests is raised to from 30 to 35 kgm. When the grain is again made coarse, the resilience becomes again weak, while the tension tests are only slightly modified by these successive treatments.

We deal here with a fact whose importance may be disputed, but whose reality is incontestable. Bending tests on notched bars on metals yield information which the other at present applied tests do not furnish. It would hence not be prudent to neglect these tests.

V. Is there any Correlation between the Results of Notched-Bar Tests and the Behaviour of Metals in Use?

This is the most important question which we have to elucidate, when we wish to take a decision from the practical stand-

oint. It has often been said, that all the incompletely understood ›sts, to which we have recourse, and in particular the various ıodifications of impact tests, are carried out with the object of ur guarding ourselves against accidental fractures in service. It /ould therefore be most interesting to establish a distinct cor- ›lation between accidental fractures, such as we have been able ılly to study in detail, and the results of tests, particularly of otched-bar tests. In order quickly to collect material for an xamination of this question Mr. Simonot has proposed to select ertain laboratories, which would charge themselves with experi- ıenting and would request engineers and constructors to send ıem the broken specimens of abnormal fractures, together with ıe most complete information concerning their manu- acture as well as the conditions under which they were ıoing duty. In waiting for the realisation of this proposal, ve have to rely on less precise information which is ıot without value, however. The cases of fracture of narine engine shafts have shown that such fractures ıre less frequent, when we take care to apply only naterials which have stood notched-bar bending tests vell. That is the conclusion at wihich Mr. Pierrard, ›ngineer in chief des Constructions Navales of the State ›f Belgium. In the French Navy which adopted notched- ›ar tests for machinery and particularly for engine- ›hafting in 1893, the results appear to have been very ›atisfactory; the results have not been published, it is rue, but the mode of testing has been generalised. In he most recent contracts for marine engine shafts ıotched-bar impact tests of the kind which we described n a note presented to the Budapest Congress[1]) are ndeed stipulated.



[1]) Extract from a specification of the French Navy for a line ›f shafting, straight, in soft steel, for the armoured vessel “Waldeck- Rousseau“.

Impact-Tests. Five bars are to be taken from each portion ›f the shaft and cut as for tension tests.

The impact tests are to be made after the method of Charpy ›n three of these bars resting on knife edges, 120 mm apart. The bars shall have a section of 30 mm over a length of 160 mm.

The notch is to be made in the middle of the bar and to consist of a hole, 8 mm in diameter, tangential to the axis of the

At the Forges de St. Jacques, at Montluçon, we have obtained very satisfactory results with the rods of steam-hammers. Up till 1901 these parts were made in soft annealed steel, and fractures were of frequent occurrence. We then began to apply a thermal treatment with the object of raising the resilience, and we verified, by means of notched-bar impact tests, the quality of each piece before fixing it in position. The life of the thus improved rods has very considerably been lengthened. We quote the results observed with two hammers, one of 8 tons, the other of 10 tons, specially used for the manufacture of railway car tyres, requiring a very uniform treatment. Before adopting the modification, the rods of the 8 tons hammer had to be exchanged 29 times in six years, and each rod lasted less than three months on average therefore. A rod of the superior resilience stood the work six years without breaking. In the case of the 10 tons hammer rod, 12 exchanges of the rod had to be effected in the course of six ye ars, each rod lasting six months on average. The new treatment reduced the number of failures to two in six years, every rod thus lasting on average three years.

Among the metallic products likely to lend themselves to instructive comparisons we must mention the armour plates. The French Navy has for several years been making use of notched-bar bending tests in order to define the quality of plates submitted and Mr. de Maupeou d'Ableiges, who was for many years president of the armour-plate commission, stated at the Brussels Congress that, in his experience, these tests constituted a very good guide in the manufacture of armour plates as regards keeping down fragility; the gun tests proved this. In a memoir presented to the Brussels Congress, Messrs. Snyders and Hackstroh, of the General Staff of the Génie of the Dutch Army, have described experiments which lead to a different conclusion;

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bar and joined to the surface by a saw-cut; thus the intact section of the bar is to be half of the total section. The hole to be pierced with a drill and to be finished with the aid of a reamer.

The tup, of the weigth of 18 kg, shall fall in the direction of the axis of the saw-cut; the hammer shall form an angle of 50^0 rounded off to a radius of 2 mm; the height of fall is always to be 1 m.

To pass, the bars must stand at least five blows without breaking; after the fifth blow they should be bent under an angle of at least 147^0, corresponding to a mean deformation of $\frac{180-147}{5} = 6^0\,30'$ maximum per blow.

armour plates of steel casting, which had given poor results in notched-bar tests, proved not fragile in the firing tests.

The contradiction between the two results seems to be more apparent than real and to be due to a confusion as to the signification of the term "fragile", which we discussed in the first section of this Report. From the fact that the material yielded a low value for the work done in fracture in notched-bar tests, we are not justified to deduce that the respective specimen will break when submitted to any test whatever. That would mean to assign to the test an absolute value which it can not possess in any manner. The notched-bar test, like any other mechanical test, can only indicate the relative value of two pieces. In order that we may be enabled to say that there is a correlation between notched-bar impact tests and firing tests of armour plates, it would suffice that, of two plates of the same form and dimensions and of the same order of hardness, the one which will prove most brittle when shot at, will also be the one that displays the smallest resilience. The memoir of Messrs. Synders and Hackstroh does not mention any comparative trials of this kind with a negative result; we believe, on the contrary, that many cases with positive results could be quoted, and we have ourselves met with such results repeatedly.

The preceding remarks are only offered as exemplifications. We think that the course of the discussions will probably bring out some precise facts. In any case it will be advisable to formulate a wish that observations of this kind should be multiplied and most minutely be classified. The International Association for Testing Materials might facilitate the collections of such documents as Mr. Simonot proposed in the article which we have already quoted.[1])

Only after having examined and discussed a great number we shall be in a position to decide, not whether it is advisable to make notched-bar bending tests, but in which cases tests should be made.

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[1]) Simonot. Réflexions au sujet des Méthodes d'essai des Pièces Métalliques—Bulletin de la Société de l'Industrie Minérale, 1907, No. 1.

"How fruitful would discussions of subjects of this kind be, and how much clearer would the problems of different tests and in particular of notched-bar tests become, if we systematically prepared specimens differing as to composition, manufacture and thermal treatment of the metals, and if these specimens were put to use, in a testing station, having carefully had the results of the various tests stamped upon them. The comparison between test values and performance would then be convincing.

Conclusions.

The mechanical tests of metals present us with a great number of scientific and technical problems which are far from being solved. To utilise the tests in industrial practice it is sufficient to regard these tests as means for the identification and classification of the metals. From this point of view none of the very numerous tests that may be proposed must be considered to be devoid of interest. As they can not all be applied in ordinary practice however, we must strive to arrange them in groups which will yield analogous results, so that we may content ourselves with carrying out one of the tests of each group. The tensile strength tests and the impact tests of notched-bars certainly belong to different groups. The latter will, with reference to the former, always furnish us with supplementary information which will be interesting, very useful, and in certain cases even necessary. It is therefore important to apply them and to compare them with other tests as well as with the experience which we gain in the practical utilisation of the respective pieces. For this object we must be able to operate according to a fixed method which will give in all cases results that will safely be comparable with one another.

We therefore propose that the Congress define a typical method, which — without being forced upon any body — would be recommended as a comparative test, and we should base the discussion on the report of Messrs. Martens, Stribeck, Lasche and Ehrensberger.

Secondly, in order that the Congress may explain the circumstances under which notched-bar impact bending tests should be applied, we propose that the Congress address an appeal to all engineers and constructors, who could give direct information, to send to duly equipped laboratories specimens in which interesting features have been observed, and that a commission be appointed for the purpose of centralising the results thus obtained and to draw up propositions to be submitted to the next Congress.

There is no want of important manufacturing establishments where a great deal of repetition work is done (for instance, the shops of automobile works), and where such experiments could be carried out without causing considerable general expense.

Why should not the International Association, which has not been able to found a laboratory of its own, invite certain laboratories and well equipped establishments to conduct tests of this nature, perhaps even allowing an indemnity in certain cases?“

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

III3

THE DEFINITION OF RESILIENCE IN IMPACT TESTS.

By **Louis Révillon,** Paris.

Translated from the French by Dr. H. Borns, London.

The following experiments have been undertaken with the object of ascertaining, under which conditions the definition of resilience, in its most restricted sense, can be taken as the same as the specific work done in fracture (spezifische Schlagarbeit), and of extending the limits of applicability beyond test pieces and rigorously defined apparatus.

When we began to refer the kilogramme-metres of a test to the square centimetre of cross-section, we admitted the possibility of comparing with one another two tests made on specimens of different dimensions.

What was the relation that might exist between unit values derived from tests of different specimens?

All the investigators have shown that it is indispensable fully to define the test bar with which they are experimenting. Our experiments have hence been made by starting from one and the same type and by enlarging or reducing all the dimensions in a certain ratio. The resulting test specimens are designated homologous.

We have served ourselves of a Guillery machine whose energy is measured by the diminution in the speed of a fly-wheel which carries the knife destined to break the specimens. The machine cannot break test-bars more than 12 mm in height, nor more than 75 mm in length; these were the limits of our ex-

periments, in which we had a maximum load of 60 kg at our disposal. The distance between the supports can be varied by shifting a moveable piece which holds the specimen and which advances in the moment of the test. This small part which we call "anvil" has been modified and, in addition to an opening of 40 mm width which is generally applied to fracture test-bars of the Mesnager type of 10 by 10 by 60 mm, we have applied three other openings of 34 mm, 28 mm, 22 mm.

The test-bars have been made on the lines indicated to the following dimensions: 10 by 10 mm with a notch, round at the bottom, 2 mm in width and 2 mm in depth; 12 by 12 mm with round notch of 2·4 mm depth; 8 by 8 mm with a notch of 1·6 mm. The lengths varied; they are entered in the table of the results.

The steel used for all the tests was always from the same casting and had been supplied to us in ample quantity in rods of 20 mm diameter. The specimens have been cut from these rods by means of cold planing; they have all been heated afterwards up to 850° and cooled in the air, in order to make the material uniform.

The analysis of the steel yielded the following percentages

Carbon	0·245
Silicon	0·20
Manganese	0·51
Sulphur	0·048
Phosphorus	0·068

These tests at once permit of drawing the following conclusions

1. The length of the test-bar has no influence on the results of the test. This is obvious *a priori*, since the excess of length is situated beyond the supports and does not intervene in the resistance values.

2. When the width of the anvil, i. e., the distance between the supports, is reduced, the gross result of the tests on specimens of the same cross section, and consequently the resistance will increase.

3. Even if rigorously similar test-bars are taken, enlarged and reduced in a certain ratio, the reduction to unit cross-sections does not yield comparable values when the specimens are broken upon the same anvil.

Table I. Variation of the length of the specimen.

Section	Opening of Anvil	Length	Value in kgm	Mean	Unit value
12 × 12	40 mm	72	30, 31, 26	29	25·3
			30, 31, 30	30	26
		60	30, 30, 30	30	26
			25, 29	27	24·25
		48	30, 28, 29	29	25·2
	34 "	60	55, 59·5. 59·5	58	50·4
		48	50, 48, 55	51	44
10 × 10	40 "	70	17, 16, 19	17·3	21·6
		60	16, 19, 17	17·3	21·6
		50	16, 15·5, 15·5	15·7	19·6
	34 "	60	20, 20·5, 21·5	20·7	25·9
		50	19, 18·5, 19·5	19	23·75
		40	19, 26, 21	22	27·5
	28 "	60	31, 31, 33	31·6	39·5
		50	34, 30, 36	33·3	41·6
		40	30, 32, 27	29·7	37·1
8 × 8	40 "	60	10, 10, 10	10	19·6
		48	10, 10, 8, 9	9·25	18
	34 "	48	9, 10, 9	9·3	18·1
		40	9, 9, 9	9	17·6
	28 "	48	14, 11, 14·5	13	25·4
		40	12, 11·5, 13	12·1	23·5
		32	12, 11·5, 13	12·1	23·5

Table II. Comparative Tests on the same anvil.

Opening of Anvil	Dimensions of Specimens	Total length	Mean length	Small length	Mean
40	12 × 12	25·6	25·1	25·2	25·5
	10 × 10	21·6	21 6	19·6	21
	8 × 8	19·6	18	19·6	18·8
34	12 × 12	58	51	19·6	54·5
	10 × 10	25·9	23·75	27·5	25·7
	8 × 8	18·1	17·6	27·5	17·9
28	10 × 10	39·5	41·6	37·1	39·4
	8 × 8	25.4	23·5	23·5	24·1

4. The results become, however, comparable, and the slight divergencies between them may be ascribed to experimental errors, when both the homologous dimensions of the test-bars and also the width of the anvil opening are varied in the same ratio.

When the results of the tests are coordinated in series, a certain agreement between the unit values of the impact tests becomes apparent; Table III needs no further comment.

Table III. **Grouping of Similar Test-Specimens in Series.**

Series	Dimensions of Specimens	Dimensions of Anvil	Experimental Values	Means reduced to cm^2
A	12 × 12 × 72 10 × 10 × 60 8 × 8 × 48	40 34 28	30, 30, 31 20, 20·5, 21·6 11, 14·5, 14	26 25·6 25·4
B	12 × 12 × 60 10 × 10 × 50 8 × 8 × 40	40 34 28	25, 29 18·5, 19·5 12, 11·5, 13	24·3 23 8 23·5
C	12 × 12 × 48 10 × 10 × 40 8 × 8 × 32	40 34 28	30, 28, 29 19, 26, 21 12, 11·5, 13	25·2 25 23·5
D	12 × 12 × 72 10 × 10 × 60 8 × 8 × 48	34 28 22	plus de 60 kgm 31, 31, 33 21, 21, 20·5	 39·5 41
E	12 × 12 × 60 10 × 10 × 50 8 × 8 × 40	34 28 22	55, 59·5, 59·5 34, 30, 36 19, 29, 25·5	50·4 41·6 47·8
F	12 × 12 × 48 10 × 10 × 40 8 × 8 × 32	34 28 22	50, 48, 55 30, 32, 27 13·5, 15·5, 17	44·3 37·1 29·9

A second series of experiments has been made on a halfhard ordinary steel of the following composition:

Carbon	0,385
Manganese	0,39
Silicon	0,27
Phosphorus	0,08
Sulphur	0,08

The test-bars were prepared and treated exactly as in the first series, cut cold with the plane notched and annealed at 800^0.

The conclusions are less definite as in the former case. This, however, is the fault of the machine. When the resistance is great, a small error will not affect the result appreciably; in the actual case, however, a relative error of 2 kg in 6 determinations means 33 per cent and spoils the value of the test entirely.

Conclusions. The experiments described would tend to prove that, in impact tests, the quantities resulting from experiments made on specimens of different dimensions may be rendered comparable by referring the quantities to the cross-sections of the plane (not-notched) bar, provided we operate always on test-bars of the same type, whose dimensions are enlarged or diminished in a certain ratio, and that the distance between the points of support, or the width of the anvil which serves as support, be varied in the same ratio.

If these first experiments were confirmed, it would suffice to adopt a certain type of test bar and to vary in all cases, and for all apparatus, the dimensions of this model and of the support, when we wish to arrive at a unification of the method of impact tests, which is alone capable of overcoming the actual opposition to such tests.

As this conception is not explicitly stated in the definition of resilience or of specific work done in fracture, it would be advantageous to make an indication to this effect.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

III4

IMPACT TESTS AT VARIABLE TEMPERATURES.

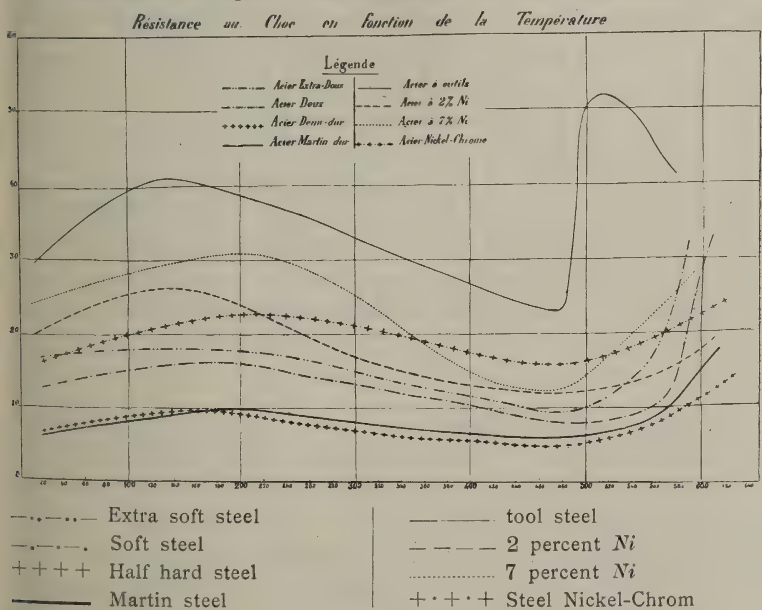
By **Léon Guillet** and **Louis Révillon**, Paris.

Translated from the French by Dr. H. Borns, London.

Mr. Charpy has shown[1]) that, when the temperature of a ecimen, submitted to an impact test, is varied, results are btained which differ with changes in temperature.

He has found that the resilience (specific work done in acture) first increases as the thermometer rises from the ordinary

Resistence to Impact Tests as function of the Temperature.



—..—..—	Extra soft steel	————	tool steel
—.—.—.	Soft steel	— — — —	2 percent *Ni*
+ + + +	Half hard steel	....	7 percent *Ni*
———	Martin steel	+ · + · +	Steel Nickel-Chrom

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[1]) Brussels Congress of the Intern. Association for Testing Materials 1906.

temperature up to about 150^0, and decreases afterwards, passing through a minimum between 400^0 and 500^0.

We have conducted a series of experiments on the variations of the resistance to impact with temperature for steels, with the special object of investigating the so-called blue-heat brittleness.

The results which we have obtained owe their interest to the observed constancy of the temperatures of maximum and minimum resistances which Mr. Charpy does not appear to have demonstrated.

The steels which have served for our researches are in the first instance a series of ordinary steels increasing in carbon percentages, the analyses of which are given in the subjoined table, and in the second instance, some special steels which served in a second series of researches, undertaken for the purpose of completing the former observations.

Number	Steel	C	Si	Mn	S	P	Treatment of the Metal
		percent					
349 y	Extra soft	0·218	1·26	0·24	0·041	0 013	Annealed in air at 850^0
407 y	soft	0·345	0·20	0·51	0·048	0·068	„ „ „ „ 800^0
342 y	half hard	0·491	0·44	0·34	00 44	0·062	„ „ „ „ 800^0
343 y	Martin	0·725	0·40	0·33	0·025	0·013	„ „ „ „ 750^0
344 y	tool	1·224	0·05	0·04	0·040	0·023	Plane bars annealed at 700^0
481 y	2 percent Ni	0·085	0·01	0·15	0·017	Ni=2·29	Annealed in air at 890^0
584 y	7 percent Ni	0·165	0·18	0·20	Ni=7·10		„ „ „ „ 600^0
225 y	Nickel-chrome	0·105	0 11	0·34	Ni=4·38	Cr=0·85	„ „ „ „ 750^0

Of each of these steels we have prepared, from the same bar, a series of 50 or 60 test-pieces of the Mesnager type, of 10 by 10 by 60 mm; the notches were made with a milling tool, 2 mm wide and 2 mm deep with a round bottom. In order to ensure uniformity of texture in the steels they have all been annealed, before the test, at a temperature which appeared most suitable to ameliorate the quality. Notes on the respective treatment will be found in the last column of the table.

Mode of Experimenting.

All the specimens have been broken in a Guillery machine n an anvil of 40 mm opening with an initial energy of 60 kgm.

They were annealed in an electric furnance, heated by latinum resistance; the ends were carefully wrapped with asbestos loth, kept in position with the aid of a small casing of sheet netal. The object of this arrangement was to prevent cooling of he extremities in contact with the clamps and with the anvil, while he specimen was resting on the machine waiting for the test. By hese means the cooling was kept very uniform, and the heat osses were confined to radiation. We have convinced ourselves hat this condition was satisfactorily fulfilled by watching the omogeneity of the red glow during the whole period that the est-pieces remained at sufficiently high temperature.

The temperatures were determined with the aid of a Le Chatelier thermo-couple. A hole of 25/10 had been pierced on the ight side of the test-bar, at the back, slightly inclined, penetrating ıp to the centre of the bar and up to about 3 mm from the cross-section to be fractured. The thermo-couple was introduced into he hole, insulated with asbestos fibre and entering under slight riction; the asbestos kept the hole tightly closed.

The Thermo-couple was joined to a precision galvanometer of Siemens and Halske.

The specimens were heated up to a certain temperature and quickly withdrawn from the furnace to be put then on the machine. The end of the thermo-couple was introduced; at the end of about 10 seconds temperature equilibrium would exist, and the galvanometer begin to fall. All the determinations were made during this period, and the specimen was broken sooner or later according to the points to be determined, as a rule as hot as possible, the temperature being read in the moment of disconnecting. The number of kgm absorbed was then entered, and the test-bar was allowed to cool in the air.

In each series two or three additional experiments were conducted at the temperature of the room, which was noted; further one experiment with a test-bar heated to 100⁰ in boiling water and broken as quickly as possible after having been placed on the machine; the interval amounted to 3 or 4 seconds.

At least two determinations were made at each of the points chosen, at intervals of 30^0 or 35^0 and often at smaller intervals in the neighbourhood of the minimum. In the diagram (Figure) the results are plotted together, the different curves being superposed.

Conclusions.

This investigation shows:

1. When the temperature of a steel is varied, the resistance to shock, having first increased up to a temperature of about 200^0 begins to fall and passes through a minimum, before it increases again, when the steel is red hot.

The temperature of maximum fragility is always the same and equal to 475^0, the temperature of incipient red glow, which is still distinctly visible in the semi-darkness, produced by the curtain of the apparatus. This temperature is not the so-called blue heat (300 or 325^0). There is no particular fragility in a steel broken at blue heat.

2. The minimum resilience exists in the special steels (*Ni* and *Ni·Cr*) tested, as well as in ordinary steels.

3. There is a maximum of resilience, less fixed, at about 150 or 200^0, depending upon the nature of the steel. At this temperature all the steels tested mark a strength of at least 10 kgm. There is, therefore, no longer any true fragility.

For one of the most brittle steels we found, e. g., 5 kgm in the cold and 10 kgm at 200^0.

4. The minimum of resilience observed at 475^0 in general goes below the value observed at ordinary temperature. This difference may amount to 6 or 7 kgm, and the diminution is all the greater, the softer the steel.

5. For the nickel-steels the difference between the minimum of resilience and its value at ordinary temperature is still more pronounced than with ordinary steels. Thus for instance: 25 kgm at ordinary temperature, 12 kgm at 475^0.

6. In the case of the *Ni-Cr* steel tested we find a remarkable constancy of the resilience with changes of temperature. It gives 16 kgm in the cold and 16 kgm at the minimum; the curve ascends very slowly, moreover, beyond the minimum.

7. A relation between the variation of the resilience and the transformation points of the steel does not appear to exist. It remains yet to be seen, how martensite steel and steel with gamma iron will behave as to fragility when the recalescence points will be lowered.

8. In no case has any sufficiently marked fragility been observed which would account for the well-known experiment that a soft steel sheet can be broken at blue heat. In our opinion one point has still to be explained:

Might there not be, as Mr. H. Le Chatelier has suggested, a greater tendency to crack or a diminished resistance to repeated blows at this temperature?

The tests, on which we report to-day, do not dispose of more than a part of the task which we had set to ourselves. We intend to inquire into the following different points:

a) Influence of repeated impacts on the resilience at different temperatures (impacts produced at variable temperature).

b) Influence of permanent definite deformations produced at different temperatures.

c) Influence of the different elements on the resilience at different temperatures.

We shall continue these experiments with nickel-steels and with nickel-chromium steels, and shall then examine tungsten steels etc.

d) Variation of the resilience with the temperature in the case of metallurgical products not belonging to the iron groups (notably brasses and bronzes) and inquiry into a possible relation between resilience and the temperature of forging.

INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

III6

APPLICATION OF MODERN TESTING METHODS TO COPPER ALLOYS.

By **Léon Guillet** and **Louis Révillon**, Paris.

Translated from the French by Dr. H. Borns, London.

We commenced this investigation with the object of ascertaining in how far the modern methods of testing used for iron and steel would be applied to other metallurgical produets and whether it would be possible to interconnect with the aid of constant coefficients the results of tensile strength tests and of other tests.

For this object we have studied:

1. The ball-test for hardness, proposed by Brinell for steels, in substitution of the determination of the tensile strength when rapid testing is desired. The different experiments have been made under a pressure reduced to 1000 kg in order to obtain, in the softer metals, smaller impressions of more regular circular shape and of well-defined outlines.

2. The shearing method of Frémont which can only be applied to very small samples. With steels the results are on the whole very satisfactory, when Frémont's coefficients are applied; the method is convenient and gives a precise value, when a test has to be made on a small bulk of material. The test bars used were 8 by 8 mm and of sufficient length to be put on the machine, from 25 to 40 mm. The value C of the resistence to shearing has directly been determined by integrating the stress-strain diagrams, and this value has been reduced to a cross-section of 1 mm.

3. The notched-bar impact test. In the first series of experiments we employed Frémont test-bars of 8 by 10 by 30 mm; in the

later experiments we generally substituted, in the place of these, bars of the Mesnager type, 10 by 10 by 60 mm, which are more convenient for breaking tests on the Guillery machine of which we availed ourselves.

All the results so far obtained and the analyses of the alloys are tabulated below. The work, it must be understood, is not completed yet, and numerous further observations will have to be taken before any rules of practical value can be given.

We have endeavoured to interpret the experiments in the following manner:

1. In order to compare the tensile strength R with the hardness number Δ we have in each case determined the coefficient of equality c such that

$$R = c\,\Delta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

which formula is already used for steels.

The values found for c are entered in columns 13 and 22 of the table. They show, it will be seen, certain fluctuations. Nevertheless, for an annealed metal, we believe, we can adopt the mean coefficient

$$C = 0{\cdot}550$$

which gives the means for brasses as well as for bronzes. The corresponding values of R [formula (1)] are well in accord with the values of direct tension tests, within ± 2 kg.

Four of our tests display a considerable discrepancy. Three of these, however, concern metals which gave very small resistances and the fourth (No. 165) must be faulty. For the elongation value is altogether abnormal; the tension test had betrayed the poor quality of the material, while the hardness test had given the number which generally goes together with the actual composition of the metal. This fact had been noticed and pointed out already in the case of steels.

For drawn crude metals the above coefficient is no longer applicable. Within the limits of our experiments, however, in which the hardening did not vary much, we might adopt an average figure

$$C = 0{\cdot}405.$$

This would be the coefficient for passing from hardness to resistance, with the express understanding that both tests are made

in zones of similar hardening (by treatment in the cold); one must not indiscriminately pass from the periphery to the centre in bulky samples.

As a rule the specimes of larger diameters yield coefficients which are higher than the means and approach those the annealed metal, since the middle portion of the bar, i. e. the least hardened (by cold working) zone, was taken in preparing the test specimen for the tensile test.

2. The formula of Frémont for steels comprises two terms; if each experiment were considered separately, it would be difficult to find any coefficients for the comparison.

To group the tests in an arbitrary manner would be illusory. We have preferred to plot out the results of the tests which we wish to compare. For each metal we obtain a point, when we take the R as abscissa, and the C, the unit resistance to shearing, as ordinate.

The study of the various points for the annealed metals has given us the formula

$$R = 5\,(C - 6)$$

We cannot say, however, how extrapolations could be made outside the range of our tests.

Some quantities, moreover, show notable discrepancies from this formula, and the experiments are still too few in number to justify our stating a rigorous law; the part due to experimental errors can not yet be determined.

If we confine ourselves in the case of drawn metals to those which have undergone the same degree of cold working, we find an analogous relation

$$0{\cdot}3\,R = C - 2{\cdot}3$$

This formula gives values which do not differ much from those of the first expression. As regards annealed metals, only those which have an exceptional resistance differ considerably, as they do in the hardness tests. Brass (No. 165), showing very slight extension, also behaves exceptionally; when the values of R are calculated, in the case of brass, from the hardness and the shearing tests, results are in accord, but the agreement with the directly determined tensile strength is not good.

3. The values obtained in the notched-bar impact tests copper alloys are always very much inferior to those given by steels, even when the alloys show greater elongations. Unfortunately we have very few experiments on this point with annealed metals, and among those there are no cases of really brittle metals; it is hence difficult to draw conclusions.

Cast Products. We have submitted some cast bronzes to the same methods of research. The first experiments are sufficient to state that, in the case of crude alloy castings, the hardness does not tell us anything about the tensile strength; the same holds for the impact test. The variations in the results of these tests follow the variations in the composition of the alloy, while in the tension tests fracture will in most cases occur quite unexpectedly. The deformations of the specimen are irregular, and the fracture is abnormal; it may take place before the elongation has been completed, near the head or at some spot which is weak owing to some impurity or to a fault in the casting.

We hope to cure these defects by an appropriate thermal treatment and to produce a homogeneous metal of good strength for which it will be possible to establish concordance between the different tests.

In resuming we should say as regards the rolled products examined:

1. From the determination of the hardness number a coefficient can be derived for the annealed metal which will, within $\pm$ 2 kg, indicate the tensile strength.

For drawn crude metals, worked in the cold under the same conditions, a comparison, with the aid of an other coefficient, is also possible, but more approximate.

2. The shearing test may also be substituted for the tension test in the case of annealed metals; the formula, expressing the correlation, consists two terms.

The drawn crude metals yield another formula which within certain limits answers almost as well for all copper alloys, ordinary or special, drawn or annealed.

The two methods can not, it will be understood, take into account any accidental defects in the strength of a metal; they give the strength value which corresponds to the composition of

he metal, while the tension test brings out more frequently aults due to the manufacture: oxides, impurities, blow-holes, or itting.

3. The impact tests could probably give more information oncerning such defects than the others. The values obtained in hese impact tests are always lower than those which steels vould yield, even when the copper alloys show considerable longation.

These conclusions are still uncertain as the number of xperiments on this point is so far insufficient.

No relations between the different tests have been found for rude castings. It will be necessary to transform the grain before he test by some suitable thermal treatment.

III6

Material		Analysis			Crude Casting			
					Tension Test		Impact	Hardness
Nature	Nos.	*Cu*	*Sn*	*Zn*	*R*	*A*%	Frémont	
Ordinary Bronzes	1	95·12	4·67		18·1	9·7	12	
	2	92·95	6·82		20·9	17	6	
	3	92·18	7·90		20·7	9	5·5	
	4	90·65	9·35		25	19	6·5	
	5	89·73	10·24		22·8	10	5·5	
	6	88·53	11·23		27·7	10	4	
	7	85·37	14·53		25·2	0·5	2·5	
	8	82·04	17·67		28·2	0·5	2	
	9	80·05	19·50		22·2	0	0·5	
	10	75·30	24·28		—	0	0	
Special Bronzes	19	91·18	7·11	1·69	22·5	31	13	6
	20	91·70	6	2·27	21·8	29	24 (*n.c.*)	6
	21	91·70	4·80	3·02	21·8	26·5	17	7
	22	91·25	3·26	5·21	21·6	31·5	16·5	6
	23	91 94	0·40	7·50	21·7	35·5	18·5	5
	24	84·54	13·50	1·49	19·5	2·5	2·5	10
	25	84·15	13·15	2·53	21·6	7·5	3	9
	26	84·77	11·58	3·37	18·7	8	3·5	8
	27	84·71	9·50	5·42	20·1	14	4·5	7
	28	85·59	7·20	6·50	16·9	15	6·5	7
	29	85·11	4·96	10·18	21·8	30	10·5	5
Aluminium Bronzes		97·00		*Al*=3·00	20·9	36	20	3
		94·88		*Al*=5·04	22·6	41	25	4
		93·13		*Al*=6·76	24·7	49	12	5

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

V[TH] CONGRESS, COPENHAGEN 1909.

IV2

QUALITY TESTS AND ENDURANCE TESTS OF COPPER WIRES.

By Professor **F. Schüle** and **E. Brunner,** of Zürich.

Translated from the German by Dr. H. Borns, London.

In view of the steadily increasing demand of copper wire for lectric conductors, especially for trolley lines, an accurate knowedge of the mechanical properties of the commercial materials nd a clear distinction of what is designated soft, half-hard, and ard copper appear desirable.

The Federal Testing Institution (Eidgenössische Materialrüfungsanstalt in Zürich) has in conjunction with the Swiss Electroechnical Association (Schweizer Elektrotechnischer Verein) conlucted an extensive inquiry into the quality of copper wires, upplied in five sizes by six firms. The results of this investigation re contained in the subjoined Tables I and II.

The soft and the hard copper wires of the several firms liffer little from one another in their mechanical properties; the alf-hard wires, it will be seen, differ considerably. Trolley wires re, near their suspension points, exposed to local bending stresses vhich are very injurious to their durability; there are in addition he tensile stresses due to the sagging of the wires and temperature ariations. On the instigation of the Swiss Railway Department the ederal Testing Institution between 1905 and 1908 has submitted 3 mm wires, of soft, half-hard, and hard copper, to endurance ending tests under different tensile stresses. The results of these ests are tabulated under III and IV; Table III concerns the quality ests, Table IV the bending tests.

It results that only hard copper can bear without breakin to and for bending, repeated for millions of times to a radius of 4 r (13 ft) under a tension of 0,2 ton/cm^2 (2845 lbs. per sq. in.). Whe the hard wire was heated up to 300^0 C. for one minute during th tinning operation, the metal was changed to such an extent tha it practically gave the test coefficients of a soft copper.

I. Series. Ordinary Quality Tests of Copper Wires.

The material at disposal of the Institution consisted of set of wires of soft, half-hard, and hard copper, diameters 1, 2, 4 6, 8 mm, supplied by six different copper works. These material were submitted to the following tests.

1. Strength tests, the tensile strength contraction of area, elon gation, and work done in fracture being determined, the latter wit the aid of stress-strain diagrams. The work done in fracture wa further determined as the product of specific tensile strength an elongation.

2. Torsion tests. The length l between clamps was 20 cm (7,87 in.), and n the number of twists which produced fracture. Th torsion coefficient was deduced from the formula $G = \frac{\pi\, d\, n}{l}$, wher d is the diameter of the wire, and n and l have the jus explained meanings. This coefficient indicates the mean patl which a point on the surface of the wire had described at th moment of fracture.

3. Impact bending tests, made with the well-known aparatus of Amsler-Laffon & Sohn, of Schaffhausen. The wires wer bent through an angle of 180^0 over a mandrel of five times th wire diameter.

II. Series. Endurance Bending Tests of Copper Wires.

These tests were carried out with the aid of a special ap paratus, constructed in the Testing Institution. Four wires car be tested at the same time, and they are bent to and fro unti fracture ensues, the height of fall, loads, and radii being ad justable at will.

The number of bendings applied was recorded by a counte which was automatically cut out by the breaking wire. The ap-

ıratus worked at the rate of about 54 double bendings per ıinute for eight or nine hours a day.

The material for these tests was supplied by Felten & Guillaume, Carlswerk, near Mülheim on the Rhine, and consisted of ›ft, half-hard, and hard 8 mm copper wires; particulars as to the ıoperties are stated in Table III. The wires were all tested as ıpplied. Sections of a number of hard wires were tinned and ;ain submitted to the same tests after cooling.

Results of Breaking Tests.

Table I.

Means of 2 Tests.

diameter d = cm	tensile strength β = tons/cm^2						Contraction of area φ = percent						elongation λ = percent						Work of Deformation per cm^3											
																			from the diagram						$\lambda\beta/100$					
	Copper works						Copper works						Copper works						Copper works						Copper works					
	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
	Soft Copper Wires.																													
0·8	2·36	2·36	2·18	2·40	2·32	2·24	72	74	72	62	61	75	40·3	39·3	45·2	39·2	34·4	40·1	0·69	0·64	0·70	0·67	0·62	0·67	0·95	0·93	0·97	0·94	0·80	0·90
0·6	2·25	2·46	2·29	2·37	2·37	2·43	72	71	69	69	69	75	39·6	38·6	40·1	38·2	37·1	36·8	0·68	0·67	0·65	0·66	0·66	0·64	0·90	0·95	0·92	0·91	0·88	0·89
0·4	2·49	2·45	2·48	2·48	2·42	2·51	72	74	66	69	68	76	36·8	38·0	38·1	34·6	31·3	36·2	0·69	0·70	0·67	0·62	0·56	0·68	0·92	0·93	0·95	0·86	0·73	0·91
0·2	2·57	2·50	2·49	2·61	2·52	2·55	62	70	68	70	74	79	39·7	35·4	36·3	36·9	35·6	30·2	0·78	0·65	0·64	0·71	0·67	0·65	1·02	0·89	0·90	0·96	0·90	0·77
0·1	2·50	2·53	2·38	2·56	2·50	2·53	63	66	75	70	77	76	34·6	29·8	36·0	35·4	34·7	32·2	0·60	0·58	0·63	0·67	0·65	0·60	0·86	0 76	0·85	0·91	0·87	0·81
	Half-hard Copper Wires.																													
0·8	2·56	3·80	3·19	2·88	2·68	3·14	68	46	57	62	61	58	21·1	2·6	4·9	15·6	20·0	3·3	0·51	0·09	0·15	0·44	0·52	0·10	0·54	0 10	0·16	0·45	0·54	0·11
0·6	2·63	3·81	3·33	3·01	2·82	3·27	62	59	60	58	64	62	9·5	2·1	4·2	9·2	14·9	3·0	0·24	0·08	0·12	0·27	0·40	0·09	0·25	0·08	0·14	0·28	0·42	0·10
0·4	2·90	4·18	3·60	3·24	3·05	3·52	67	47	61	64	64	63	13·0	2·0	3·2	3 9	4·8	1·6	0·37	0·07	0·11	0·11	0·13	0·05	0·38	0·08	0·12	0·12	0·14	0·06
0 2	3·50	4·11	3·84	3·59	3·54	4·04	65	52	52	59	63	50	2·9	1·4	1·4	1·6	2·7	1·1	0·09	0·05	0·04	0·05	0·09	0·04	0·10	0·06	0·05	0·06	0·09	0·05
0·1	3·56	3·75	3·94	3·06	2·90	3·72	55	53	48	61	65	59	0·9	1·1	0·8	1·8	3·1	1·0	0·03	0·04	0·03	0·05	0·09	0·03	0·03	0·04	0·03	0·05	0·09	0·04
	Hard Copper Wires.																													
0·8	3·38	3·63	3·90	3·93	3·70	4·14	56	51	47	45	45	49	2·4	3·0	3·0	4·0	3·2	2·2	0·07	0·10	0·11	0·15	0·11	0·08	0·08	0·11	0·12	0·16	0·12	0·09
0·6	3·79	3·96	3·61	4·00	3·73	4·38	59	45	53	47	50	50	2·2	2·2	3·3	2·6	3·0	1·8	0·07	0·08	0·11	0·09	0·10	0·07	0·08	0·09	0·12	0·10	0·11	0 08
0·4	4·22	4 28	4·03	4·30	4·00	4·30	52	51	44	54	49	47	2·7	1·7	2·1	1·8	2·5	1·5	0·10	0·06	0·07	0·07	0·09	0·06	0·11	0·07	0·08	0·08	0·10	0 07
0·2	4·12	4·78	4·50	4·61	4·29	4·47	47	37	46	40	50	41	1·2	1·0	1·4	1·2	1·5	1·0	0·04	0·04	0·05	0·05	0·06	0·04	0·05	0·05	0·06	0 06	0·07	0·05
0·1	3·94	3·56	4·16	4·02	4·12	4·50	50	44	55	51	48	51	1·0	0·7	1·0	1·1	0·9	1·1	0·03	0·02	0 03	0·03	0·03	0·04	0·04	0·03	0·04	0·04	0·04	0·05

Results of Torsion and Impact Bending Tests.

Means of 2 or 3 Experiments.

Wire diam. d = cm	Number of Twists						Coefficient of Torsion S						Wire bent through 180° Times						Remarks
	Copper works						Copper works						Copper works						
	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	
Soft Copper Wires.																			
0·8	21·1	20·7	28·1	24·3	23·8	30·3	4·12	3·98	4·93	3·46	3·27	4·42	9	9	9	7	8	9	
0·6	33·9	27·3	33·4	34·5	33·2	39 3	4·34	3·80	4·03	3·87	3·84	4·28	9	8	8	8	8	5	[1]) Broken in free portion; in all other cases near shoulder.
0·4	47·0	46·2	44·5	48·2	[1])62·9	[1])63·4	4·16	3 94	2·91	3·37	3·99	3·99	8	10	6	7	7	6	
0·2	82·2	89·2	67·4	93·8	[1])115·5	[1])93·7	3·93	3 96	3·30	3·73	3·64	2·96	11	14	10	10	10	9	
0·1	167·8	163·7	172·9	182·2	193·4	176·6	3·26	2·98	3·39	4·51	4·37	3·10	12	8	11	15	11	11	
Half-hard Copper Wires.																			
0·8	27·8	7·2	21·1	25·9	[2])19·7	24·1	3·51	0 91	2·65	3·25	3·06	3·04	8	4	4	7	5	4	
0·6	31·2	16·7	36·4	[3])19·1	37·0	29·9	3·20	1·58	3·44	[3])0·84	3·62	2·85	7	5	7	5	7	7	
0·4	53·3	41·4	53·3	54·3	49·2	66·1	3·39	2·62	3·36	3·42	3·10	4·16	7	3	6	6	5	7	
0·2	89·9	94·8	84·4	[2])116·3	106·4	96·0	3·22	3·03	2·62	3·80	3·30	3·03	10	7	4	7	9	6	
0·1	130·2	150·9	145·1	240·4	[2])210·2	59·8	2·06	2·35	2·25	3·87	4·00	0·93	9	9	7	15	13	6	[2]) Broken near shoulder.
Hard Copper Wires.																			[3]) Material not intact.
0·8	9·2	15·1	11·0	7·5	13·4	18·0	1·17	1·91	1·42	0·94	1·68	2·27	5	4	4	5	4	4	
0·6	16·2	10·9	23·1	19·9	31·0	17·8	1·54	1·01	2·17	1·88	2·92	1·69	6	3	4	3	4	4	
0·4	39·2	31·3	18·7	43·0	31·0	30·6	2·46	1·91	1·19	2·68	1·94	1·94	4	5	2	5	4	4	
0·2	71·8	44·0	60·7	53·7	77·1	64·7	2·27	1·41	1·92	1·69	2·39	2·01	6	2	6	6	7	4	
0·1	[2])85·8	42·8	170·8	51·5	66·4	79·2	1·70	0·66	2·73	0·82	1·06	1·27	8	4	6	6	6	8	

Table III.

Results of Quality Tests of Copper Wire, 8 mm in diameter used for Endurance tests.

Kind of Wire	Breaking Tests			Torsion Tests		Impact Bending Tests	Remarks
	Tensile Strength β = tons/cm²	Elongation on 15 cm λ = per cent	Work of Deformation $\frac{\beta \cdot \lambda}{100}$	Wire Twisted over $l = 20$ cm n Times	Coefficient of Torsion $\frac{n \cdot \pi \cdot d}{l}$	Wire bent over mandrel of 4 cm diam. through 180°	
1. Set of Samples. Means of 2 or 3 Experiments.							
Soft	2·44	38·25	0·94	20·6	2·59	7	
half-hard . .	3·04	8·00	0·24	24·7	3·11	6	
hard	3·99	3·28	0·13	9·7	1·21	8	
hard, tinned at 270 to 280° C.	3·90	3·73	0·15	11·9	1·39	6	
2. Set of Samples. Means of 3 Experiments.							
Soft	2·42	38·49	0·93	18·7	2·35	5	
half-hard . .	3·02	4·97	0·15	18·9	2·38	5	
hard	4·06	3·51	0·14	14·7	1·85	5	
hard, tinned at 300° C. for one minute	2·57	23·92	0·61	16·9	2·12	7	

Results of Endurance Tests.

Kind of Wire	Bending radius m	100	200	400	600	Bending radius m	100	200	400	600
		Wire bent to and fro until breaking at a load of — kg.								
	Height of fall 17 cm	I. Set of Samples				Height of fall 6 cm	II. Set of Samples			
soft	1·0	6.777	7.811	10.545	1.728	4·0	587.375	496.010	452.090	452.642
"	0·5	2.501	2.260	2.528	323	2 0	53.377	57.028	78.380	83.036
"	0·2	1.210	1.104	177	82	1·0	48.025	29.735	46 598	66.377
"	0·1	1.188	419	72	35	—	—	—	—	—
halfhard	1·0	6.492	6.347	7.629	3.832	4·0	2,326.935	1,420.927	1,078.327	484.758
"	0·5	1.655	1.395	3.352	453	2·0	195.055	102.450	61 536	56 987
"	0·2	807	564	165	77	1·0	126.055	66.195	28.012	22.229
"	0·1	626	228	59	29	—	—	—	—	—
hard	1·0	7.455	7.950	6.960	5.750	4·0	[2]4,750.610	3,440.375	1,730.905	792.801
"	0·5	2.372	1.579	999	636	2·0	996.466	278.002	284.901	138.365
"	0·2	1.205	903	153	81	1·0	737.871	122.062	93.291	36.789
"	0·1	818	347	55	26	—	—	—	—	—
hard, tinned at 270° C.	1·0	10·524	10.873	15.720	3 674	[1]4·0	2,503.700	1,158.429	706.728	620.192
	0·5	2.444	2.796	3.072	330	[1]2·0	172.579	115.482	100.675	129 287
	0·2	2.182	909	240	106	[1]1·0	129.730	46.536	48.034	55.256
	0·1	1.510	610	90	36	—	—	—	—	—

[1]) Tinned for 1 Minute at 300° C.

[2]) Not broken.

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A NEW MIRROR APPARATUS FOR MEASUREMENTS OF ELASTICITY.

By Professor **B. Kirsch,** Vienna.

Translated from the German by Dr. H. Borns, London.

Those who have to take many measurements of elasticity ppreciate the advantages of easily manipulated apparatus. The st mirror apparatus, the extensometer of Bauschinger, worked ccellently. That it has recently been replaced by the splendid pparatus of Martens is chiefly due to the fact, that the latter is easily mounted. As regards the primary requisites, accuracy of e measurements and control of the scale of magnification, the o instruments are regarded as equally excellent. If I have designed new apparatus, my reason has been that both Bauschinger's ller and Martens' prisms are subject to wear and have hence be kept under continuous control.

I need not enter into a detailed description of the two wellnown apparatuses and will confine myself to the principal points. Bauschinger's apparatus the small elastic extension of the ecimen is made to turn a little roller of hard rubber R (fig. 1) gainst which the small steel bar S is rubbing. The mirror is ounted on the axis of the roller. The spindle of the roller is gidly coupled with the one mark on the rod, the bar with the her mark; thus the displacement of the bar relatively to the indle of the roller will be equal to the change in length to be easured. The diameter of the roller must accurately be known d be the same in all directions.

In the apparatus of Martens the bar S (fig. 2) is provided with a notch N, into which the prism P fits. The change in the length, that is to say, the displacement of S, which is again joined to the one mark on the rod, will tilt the prism which rests at A in the second mark. A mirror attached to the side of P will participate in the turning of P about the point A and is utilised for taking measurements. The distance between the two knife-edges must accurately be known and must be constant.

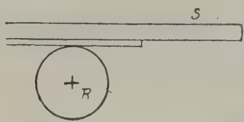


Fig. 1.

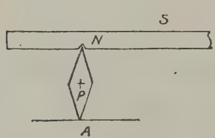


Fig. 2.

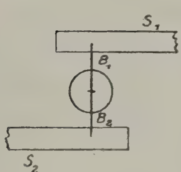


Fig. 3.

The new apparatus, which Amsler & Sohn, of Schaffhausen, have constructed to my design, is illustrated in the diagram, fig. 3.

The two bars S_1 and S_2, the one of which lies on the first mark, the other on the second mark of the rod, are displaced with regard to one another by the amount of the extension. The two rails are connected by the band spring of steel B_1 B_2, about 0,1 mm in thickness, which is fixed into the two bars; the displacement of the bars S_1 and S_2 causes the spring to assume an S curvature. The central portion of the spring supports the spindle of the mirror which is fixed to the side of the spring; the mirror will turn when the spring is curved, and its angular movement will, as a simple calculation would demonstrate, be proportional to the displacement of S_1 with regard to S_2.

This extensometer does not contain any parts which are subject to wear, and the scale, once determined, will remain unchanged. Mirror and bars form one piece which is very readily mounted. The test length is given by the apparatus; gauge marks need not be made on the specimen. The rotation of the mirror is a little greater than in the other instruments.

In determining the scale of magnification, I fix one fragment of a specimen on the movable table of a dividing machine, the other fragment to the frame of the machine. The apparatus is mounted on the fragments across the gap between them as if an extension test were to be conducted (fig. 4). The travel of the

novable table is determined with the aid of a microscope and a tandard scale, and mirror readings are taken at the same time. This method of control is more exact than any other.

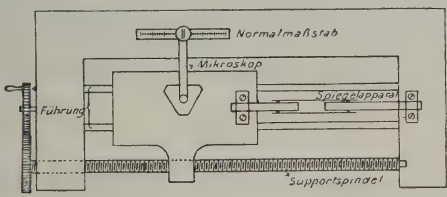
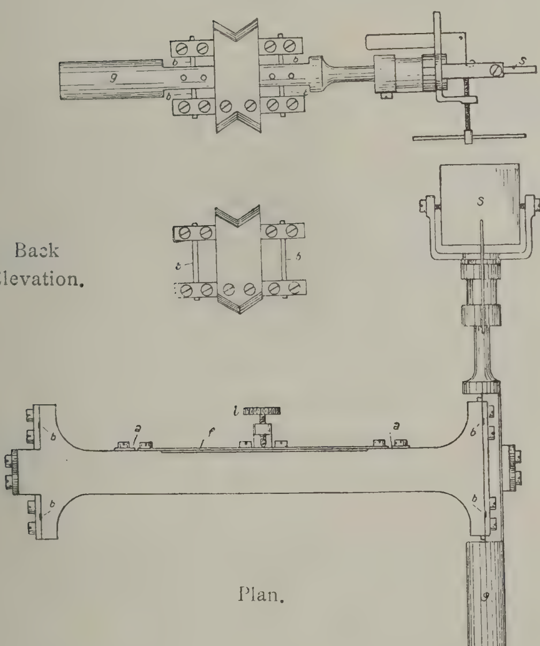


Fig. 4.

Front Elevation.

Back Elevation.

Plan.



Scale 2 : 3.

Fig. 5.

Fig. 5 illustrates the apparatus in the scale 2 : 3. The most mportant parts, the two springs which bend to S shape, are ndicated by the letter *b*; S is the mirror, and G its counterpoise.

The stops at *a* prevent too large a curvature of the springs. The screw *l* puts the springs *b* under a small tension and counteracts any tendency to bend. The apparatus remains in this condition until a measurement is to be made, and the screw *l* should only be released while the measurement proceeds. The apparatus, which was described in the "Österr. Wochenschrift f. d. öffentl. Baudienst", 1908, Nr. 51, has given perfect satisfaction.

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VIII7

:PARKS AS INDICATIONS OF THE DIFFERENT KINDS OF STEEL.

By **Max Bermann**, Budapest (Hungary)

(Translated by A. R. Liddell, Charlottenburg.)

In the grinding of Iron Materials by means of emery wheels ginding-sparks are given off.

According to their dimensions and their edges and angles (section, as also to the pressure at the surface of contact ttween the metal and the wheel, the sharp edges of the emery cystals detach chips of different, but certainly very small sizes, a a very high velocity. The mechanical work hereby transformed i:o heat raises the temperature of the chip to a red heat.

The glowing chip is thrown off with the peripheral vlocity of the emery wheel, and forms the grinding-spark. lhe crystals thus crumbled from the emery wheel are also thrown c; but they are not red-hot, and cannot therefore be mistaken fc the sparks.

The path described by the spark from its origin to its disapearance (the extinction of the spark is equivalent to its disapearance) forms a line of light which we shall call the sark-ray.

The length of the spark-ray varies very considerably, and dpends upon the size, and therefore upon the mass, of the sark.

The larger sparks fly to greater distances, the smaller ones t(distances of a few centimetres or a few millimetres. The size) the sparks depends principally upon the size of grain of the

emery, the speed of cutting, the nature of the metal to be ground and the pressure with which the wheel is made to bear agains the metal. The initial temperature of the sparks is influence principally by the cutting power and cutting speed of the emer wheel, and in a minor degree by the nature of the iron materia to be ground.

The influence of the emery wheel, however, by far outweigh that of the quality of the iron.

Fig. 1.
Spark-Sheaf of a Hard Carbon Steel.

If we consider a spark-ray of soft steel (wrought iron), say one o the longer rays, we see that it forms quite fair line of light, the end o which assumes the form of an extende drop (the point of the drop lies toward the front in the direction of flight of th spark). The heat of this drop-formatio varies between a bright red and a whit glow, and on closer observation w find that its pointed dark red end i extended so as to form a second muc smaller drop. At the point at whic the first drop formation is broa dest, i. e. where it is of a whit heat, it branches out, pointe prickle-like lines rushing out o it in every directions with a explosion-like appearance. Th pointed branching lines have, in th lateral projection, a forked appearanc while in the direction of their fligh they look as if rushing from a ver brightly-glancing knot shooting forward in an explosion-lik manner and disappearing in a moment.

This explosion-like appearance and articulation o the sparkray is different in the cases of different kind of iron, and is in fact characteristic for these.

We shall give this phenomenon, which is the characteristi form of the articulation, the name of the spark-picture.

The spark-picture of the carbon-steel is the tuft of prickle like lines.

With a percentage of carbon of 0·07 to 0·08 the number of ese lines is from 2 to 3, and these appear to start from differ- it points of the brightly shining drop-formation. With an increase the percentage of carbon the number of the branching lines so increases. With 0·25 to 0·27 per cent of carbon a crowd of ickle-lines appear, and they spring from a common point of the op-formation. With a still larger percentage of carbon the prickle- nes cover a correspondingly large part of the drop-formation ith a proportionately greater clo- eness of crowding.

The numbers of the prickle- nes in the spark-formation re proportional to the percen- ges of carbon contained by e different kinds of steel, so at conclusions may be for- ed from them in regard to the tter.

The spark-picture of steel which ontains manganese is so characteri- ic, that it is almost impossible to istake it for that of any other kind steel. The ends of the individual ranching lines in this case are no nger pointed, but in each instance now a secondary explosion-like henomenon, in so far as shorter nes collect like leaves round a ommon central point.

Fig. 2.
Spark-Sheaf of a Tool Steel rich in Manganese.

This leafy end of the branching nes in the spark-picture characterizes e manganic steel. The number and e closeness of the primary branching lines springing from the op-formation are again the greater, the larger the percentage the carbon in the steel. The extent and the shape of the spreading nds of the primary branching lines appear to stand in connection ith the percentage of manganese contained by the material.

In the case of crucible cast-steel the spark-picture resembles e branch of a blossom, and the individual branching lines have

a lilac-like form. This enables the crucible cast-steel to be distinguished from other kinds, as for instance from Siemens-Martin steel, by means of the spark-test.

Not less characteristic, and thereby surprisingly easy to recognize, is the spark-picture of steel containing wolfram. The spark-rays are dark red hatch-stroked lines, the ends of which show no spark-picture when the emery wheel is not sufficiently sharp and the pressure between wheel and steel is small, and only the last little stroke in the spark-ray, which has a broader and more brightly-glowing appearance points to the beginning of a spark-picture.

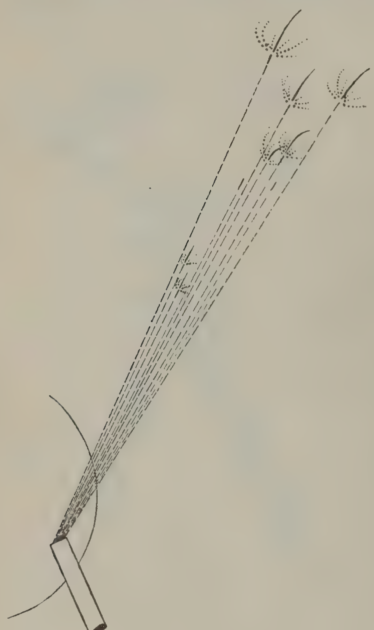

Fig. 3.
Spark-Sheaf of a Special Steel rich in Wolfram.

If we cause the steel to bear with a greater pressure against the emery-wheel, the drop-formation appears at the end of the spark-rays, and out of it spring the branching lines in an explosion-like manner. The ends of these lines, however, are neither pointed nor leaf-like, but take the forms of little shining pin-head-like balls. Beside the little balls the branch lines are scarcely visible and the appearance of the whole is as if the shining balls were thrown directly out of the drop-formation.

The spark-sheaf (the combination of the spark-rays and spark-pictures) of the chrome-wolfram steel (high-speed-steel) is distinguished from that of the wolfram steel by the circumstance that two kinds of ray appear, viz. very thin dark red and thicker brick-red ones which are absent in wolfram steel. The spark-pictures of the high-speed steel consist solely of short curved drop-formations. In many kinds, such for instance, as Böhler Rapid, Mark P 11, solitary long needle-shaped lines with clubbed ends shooting out from a central point also make their appearance. These may be

ken to show one or other of the subsidiary alloy metals, such s are made use of in the manufacture of high-speed steels.

The drop-formations of the spark-sheaf have a strikingly igher speed of flight, and look as if they were suddenly thrown a greater distance in the direction of their flight by an internal force.

The spark-picture of nickeliferous steel is completely identical ith that of carbon-steel with corresponding percentage of carbon nd reduced percentage of nickel (3 per ent *Ni*). In case of a larger percentage f nickel (nickel-steel), however, the ickel steel can very readily be re-ognized by the aid of the spark-test, ecause in connection with it the spark-ictures only show themselves in a poradic fashion here and there, where-s in the case of carbon steel they ccur in close proximity and in close uccession to one another.

Fig. 4.
Spark-Shear of a Molybdenum Rapid Steel.

In accordance with its composition, nd more especially with its percentage f carbon and manganese, cast-iron gives spark-pictures which differ from ne another. The drop-formation is in every case present. The branching lines ange themselves very closely along he brightly shining part and, in accor-lance with the relative percentage of nanganese, show ends of more blunted r more leafy appearance.

On the basis of this description f the characteristic spark-formations ve are now able to recognize the different kinds of iron and steel, to distinguish them one from another, eventually to establish heir identity, and, by dint of special practice with analysed naterial and the use of standards, to determine the exact percentage f amalgamated carbon in each kind of iron.

Proficiency in the judgment of the spark-formation can be nuch more easily attained when an acceptable explanation of the spark-pictures is forthcoming.

The facts and indications which provided me with a basi
for this explanation are the following:

1. At a certain point in its line of flight the red-hot sparl assumes a yellow heat; it then reaches a white heat, thereby transforming itself in an explosion-like manner into the spark picture.

2. At the moment of its explosion-like transformation th spark is in the fluid state.

In regard to 1, a proof need hardly be given. The fluic condition of the spark, however, is not apparent without close investigation. If we introduce a plate of glass at right angles t the line of flight of the sheaf of sparks, it will become coverec with extinct sparks. The microscopical examination shows tha

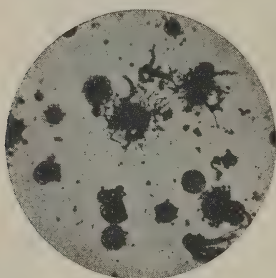

Fig. 5.
Extinct Sparks of Nickel-Iron adhering to the Glass Plate.

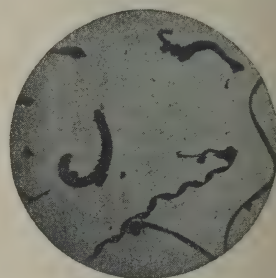

Fig. 6.
Extinct unfused Sparks of Nickel-Iron collected on a Glass Plate.

part of the sparks reach the glass plate in an already fluid condition and crystalize there in the most diverse relievo forms, or splashe asunder (Fig. 5), while another part adheres to it only loosely and can be easily rubbed off. This latter kind consists of chips of various forms corresponding with the various cutting and bearing angles of the emery crystals (Fig. 6).

A further proof for the fusion of the sparks is afforded us by the examination of the grinding-dust which has fallen unhindered to the ground (a mixture of emery-crystals and extinct sparks). By the aid even of an ordinary magnifying-glass we see, side by side with chips of iron, little smooth shining black and blue balls, which unquestionably point to a chill in a fluid condition.

And now for an explanation of the facts:

The increase of heat of the spark (where an extinction due to rapid cooling would more reasonably have been expected) was caused by an internal source of heat, represented on the one hand by the transformation-heat of the kind of carbon in question at the critical temperature produced by cooling, and on the other by the combustion-heat of the transformed carbon which in the status nascens suddenly burns. The heat of oxidation of the exterior surface of the mass of sparks acts in opposition to the too rapid cooling of the spark. The quantity of oxygen necessary for the combustion of the carbon is now supplied by the crust of black oxide of iron, which, up to the point of critical temperature, had been formed.

The heat of combustion of the carbon constituent provides the quantity of heat necessary for the fusion of the mass of sparks. As a matter of fact, however, this heat is not sufficient to melt the whole mass, because the amount of the carbon is too small. A melting of the spark takes place when the mass of the unoxidised core within the oxidized iron crust is small enough to be melted by the quantity of heat available. In this case the combustion-gases of the amalgamated carbon burst the outer crust of the spark-mass and thrust out the fluid contents in the direction of the primary branching lines. The silicium and phosphorus therein contained also burn at the melting heat of the iron and raise the temperature of the fluid mass.

From this explanation it follows, that the size of the fusible spark increases with the percentage of amalgamated carbon, while the quantity of the fluid core and the tension of the combustion-gases are correspondingly greater and the branching lines more numerous.

We now have the explanation of the circumstance that the percentage of assimilated carbon bears definite relation to the number of the branching lines in the spark-picture, and are also in possession of the proof of the fact, that not all sparks give spark-pictures.

It must command attention that in spite of the explosion-like articulation of the spark-picture at one point of the line of light, the branching lines often appear at different points of the drop-formation. I find the explanation of this in the difference of

the speed along the line of flight, and at right angles to it, after the bursting of the spark-crust.[1])

The practical applicability of the spark-test is manifold. The most important instances of it may be shortly given as follows:

1. The classification of the different kinds of iron in accordance with "percentage of carbon" and "principal alloy-metal".

The ends of rods which may eventually have been wrongly arranged in the storing-rooms of the iron-working industries are made to bear against the revolving emery wheel. The shape of the spark-picture gives unerring indication of the kind of iron to which the rod in question belongs. Pointed branching lines in the spark-picture denote carbon-steel, e. g. Siemens-Martin steel: leafy ends of the branching lines a manganic steel (Siemens-Martin steel with larger percentage of carbon). Spark-pictures with a blossom-branch-like arrangement indicate ordinary tool-steel: dard-red-stroked spark-rays and shinig points and little balls thrown out of the drop-formation, wolfram steel; two different kinds of spark-rays of dark red and brick-red colour, respectively, with short unarticulated drop-formation, high-speed steel with chrome and wolfram as alloy elements; when explosion-like articulation is present, a secondary-alloy metal (molybdenum, vanadium, or titanium) is in question.

2. The spark-test is so sensitive, that it gives strikingly clear indication of a difference of 0,01 per cent of carbon, and it accordingly offers a very simple and rapid check on the chemical analysis in regard to the amalgamated carbon in steel, and also forms a suitable check on the Siemens-Martin process (in place of the forge-test), in particular when analysed standards are made use of for comparison. The assay sample is chilled and the sparks compared with those of the standard. The carbon in the charge is then increased or lessened, according to the differences which show themselves.

3. At the taking-over of different kinds of iron the sparktest supplies a sure means of excluding material which does

[1]) In regard to the other spark-pictures and details, I must, in view of the limited space at disposal, refer to my article "Die Funken als Erkennungszeichen der Stahlsorten" (The sparks as marks of recognition of the different kinds of steel) which appeared in the "Zeitschrift des Vereins deutscher Ingenieure", 1909, No 5, Vol. 53.

ıot comply with the conditions. When a suitable sample is available, t is only necessary for the testing official to satisfy himself of its dentity with the material offered, by comparison of the spark-pictures.

The material for quality tests is chosen from charges vhich give spark-pictures identical with those of the amples, and from such the spark-pictures of which show onsiderable difference. At the test, these latter will show hemselves as not in accordance with the conditions.

4. The spark-test supplies a very sensitive means of establishing vith certainty any differences there may be in the chemical omposition at different points in the iron product, and ılso in finished objects and structural parts (see Point 2).

5. The spark-sheaf and the spark-pictures provide he possibility of at once determining, whether a cast-ron is grey or white, and also of distinguishing shades of difference in the individual varieties.

Fine dark-red spark-rays, spark-pictures here and there, and ines collecting round the drop-formation like a net, formed by the eaf-like articulation lines, denote black or very dark grey ast-iron: spark-pictures corresponding with manganic steel, grey ast-iron. The net-like lines retreat more and more with the ncrease of the assimilated carbon, and with light grey cast-iron hey disappear altogether.

6. In shop work the spark-test, when once introduced, is not asily done without. In the hardening room counsel is taken vith the spark prior to the hardening of the tools (which are oday made of steel of the most varied kinds), to avoid the ccurrence of gross mistakes in the hardening temperature applied. he wire for the manufacture of different spiral springs s likewise examined with the emery wheel, to see whether t has the degree of hardness suitable to the purpose n view.

In the forge, the spark is applied to the distinction f good malleable wrought iron from such as is difficult o weld, etc.

The importance of making a process of such simplicity vailable for general practical purposes, may perhaps repay the rouble of closer attention. It affords me satisfaction to have done ny part towards such a consummation.

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VIII8

ON THE PRINCIPLES OF "TECHNOLOGICAL MECHANICS".

By Dr. techn. **Paul Ludwik**, Vienna.

(From a preliminary Communication in the "Österr. Wochenschrift für den öffentlichen Baudienst", 1908, No. 42, p. 762.)

Translated from the German by Dr. H. Borns, London.

Let the body consist of elastic elements (molecular groups, articles of matter) which are in contact and which may (under ertain conditions) permanently be displaced with regard to one nother. Let the dimensions of these elements vanish by compari- on with the deformations under consideration, and let the whole ody be homogeneous and isotropic. The specific tangential force shear stress), which is required to produce a relative lasting dis- lacement of the elements, may be designated "internal friction"[1]).

Making the assumption that elastic strains are based upon he elastic deformability of the elements[2]), it can be shown that ny permanent deformation consists, on the one hand, in a ermanent relative displacement of the elements along two ystems of planes situated symmetrically to the chief stresses and,

[1]) In general the internal friction increases with the hardness, the specific hear, the tensile stress normal to the sliding plane, and with the rate of yielding; ut the magnitudes of these influences differ considerably with different materials.

These features also distinguish the limiting types of "solid" and of "fluid" odies; for the state of rest (that is, for zero velocity of displacement) we have n the former case $R > O$; in the latter case — in spite of the cohesion which nay not be inconsiderable — $R = O$.

[2]) The real causes of the elastic deformability are not yet understood; for he present we have to be satisfied with "explaining" the elastic deformability, which is observed in the body as a whole, by a corresponding property of the lements.

on the other hand, in a relative torsion of these planes with regard to the original material, which torsion increases with progressive deformation.

Under the common influence of γ and β (magnitude and nature of the previous specific shear) on the magnitude of the internal friction the originally homogeneous and isotropic material becomes more or less homeotropic (according to the magnitude of this influence).

It would result from torsional tests made with previously stretched copper and brass, from comparative tension and compression tests of copper, and steel, as well as from comparative tension and torsion tests of copper, brass, french-beck metal, packfong and steel that the influence of the torsion β upon the magnitude of the internal friction is generally subordinate to that of the shear γ, and that it is hence above all the relation between internal friction and specific shear which characterises the behaviourof a strained material and the alteration in the degree of fluidity in the flow phenomena. This relation may therefore briefly be termed the "flow curve" (the specific shears being understood as abscissae, and the internal frictions as ordinates).

The higher the starting-point of this curve, the harder will be the "original material"; the steeper the curve, the more intense will be the hardening by working in the cold which the material undergoes under increasing strain, and the greater will be the deformation resistance which the material will oppose to further working in the cold; the later the curve attains its culmination, the more "plastic" it will be.[3])

The importance of the "flow curve" for testing materials is further proved by the fact that — as the experiments mentioned confirm — both the tension and the compression diagrams as well as the torsion diagram (this last point should be emphasised) can be deduced from it.

It resulted moreover that the torsion test, which so far is so little appreciated in testing materials, admits of a much more complete determination of the "flow curve" than tension and compression tests.

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[3]) Compare also: P. Ludwik, "Über Zähigkeit und Schmeidigkeit", "Zeitschrift für Werkzeugmaschinen und Werkzeuge", 1908, No. 23, p. 327.

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VIII9

INTERNAL FRICTION IN LOADED MATERIALS.

3y **G. H. Gulliver**, B. Sc., F. R. S. E., A. M. I. Mech. E., of Edinburgh.

The beautiful experimental researches of Hartmann[1]), in ombination with a theory of internal friction which seems to have een due originally to Navier, have been utilised by Mesnager,[2]) Rejto[3]), and others in some interesting memoirs. The writer also, n a number of occasions, has sought to employ, and in some espects to amplify these methods; and a brief summary of certain esults obtained in this manner are given herein.

The Inclination of the Lines of Lüders to the Direction of Stress.

Experiments were begun merely as a repetition of some of hose described by Hartmann. In the first place, soft steel bars f various shapes were loaded in tension to somewhat above the ield point, so that the lines of Lüders were fairly numerous nd well defined. The inclination of these lines to the direction of tress was measured, and was found to be very nearly constant, s mean value being about 50^0. In Hartmann's experiments this ngle varied between 65^0 and 53^0, according to the material, but oft steel does not appear to have been tried. Subsequently, the riter found that a soft steel bar, of which the width was several

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[1]) "Distribution des déformations dans les métaux", Paris, Berger-Levrault et Cie., 896; and Congrès International des Méthodes d'Essai, 1900, I., 95.

[2]) Comptes Rendus, CXXVI, 1898, 515; and Congrès International des Méthodes d'Essai, 1900, I, 143.

[3]) Congrès International des Méthodes d'Essai, 1900, I, 185.

times the thickness, broke across its wider faces in a direction inclined at about 65^0 to the direction of tension.

These varied results left considerable doubt as to the nature and regularity of the phenomenon, and it was felt that further experiments were desirable. A number of thin, flat, steel bars were accordingly prepared, and carefully tested in tension. The results showed, in a most definite manner, that at least two distinct phenomena occur during the period of large deformations of such a bar[1]). First, at the yield point of the material, the lines of Lüders appear—either suddenly, as isolated local deformations, or as a kind of strain wave advancing gradually along the bar — and these have an inclination which, as already stated, approximates to 50^0. After the yield point is passed, the bar, as is well known, stretches uniformly throughout its length during a more or less extended range of loading, until a stress is reached at which the deformation becomes localised, and the bar is constricted. It is when this constriction has somewhat progressed, and the material is very near its breaking point, that the second phenomenon takes place. It is revealed usually by two narrow grooves upon each wide face of the specimen; these grooves intersect each other at the middle of the face, and are inclined at about 65^0 to the direction of tension. If the load is increased sufficiently, the bar breaks along one or other of the grooves. This phenomenon is known as the Contractile Cross. Sometimes more than two grooves can be seen, and frequently only one is present.

In a number of ways, all of which need not be detailed here, it was shown that the lines of Lüders and the contractile cross are two distinct phenomena. The contractile cross is found in metals other than steel, provided that they are in a ductile condition, and it has been obtained with thin flat bars of copper, brass, german silver, and aluminium. The inclination of the grooves always approximates to 65^0, and this suggests that the cross is a flow phenomenon, intimately connected with that of constriction generally. On the other hand, the lines of Lüders, so far as the writer's experience goes, are found only upon iron and steel — metals which have a well marked yield point. Other metals, when permanently deformed, show a general roughening of the surface

[1]) Proc. Inst. Mech. Eng., February 1905, 141.

ut not the banded appearance so frequently associated with the nes of Lüders.

It should be noticed however, that Hartmann claims to have btained Lüders' lines upon platinum, silver, aluminium, copper, n, lead, zinc, and upon bronze, brass, delta metal, and german ilver, while Mengin[1]) has found them upon aluminium, delta metal nd brass. But the writer, from the results of his own experiments ith most of the above metals and alloys, is of opinion that what ese investigators really obtained were contractile depressions. This pinion is supported by both the published descriptions of the henomena and also by the illustrations and the values of the ngles given by Hartmann.

The contractile cross has been obtained only upon bars having width considerably greater than their thickness. When the ratio f width to thickness is less than 4, the cross becomes indistinct, nd it is hardly noticeable upon bars of square section. Moreover, e inclination of fractured surfaces of steel tensile specimens, xcept under the particular conditions cited, is certainly not 65^0, ut is approximately 50^0. Even with a thin flat bar this inclination, measured parallel to the narrow face of the specimen, instead of the wide face, is about 50^0. So that it may be said, generally, that e angle of fracture in tension is, at least approximately, the same s that of the lines of Lüders, except when the existence of the conactile cross rules otherwise. Confirmatory evidence is afforded by the iclination of the fractured surface of a round steel bar broken by rsion; this surface is inclined at 50^0 to the direction of principal ension — that is, at 85^0 to the longitudinal axis of the bar[2]).

Microscopic examination shows that the minute process of eformation remains the same after the appearance of the conactile cross as before[3]) — namely, that it is the result of slidings hich take place along the cleavage planes of the crystalline ggregates, and are rendered evident by the "slip bands" of Ewing nd Rosenhain[4]). Another observation is that the general directions f movement, revealed by the lines of Lüders and by the conactile cross, are subject to local variations due to the changing ositions of the cleavage planes of the crystalline aggregates.

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1) Comptes-Rendus 124, 1897, 681.

2) Proc. Inst. Mech. Eng., July 1907, 753.

3) Proc. Inst. Mech. Eng., May 1907, 519.

4) Phil. Trans., 193 A, 1900, 353.

The Coefficient of Internal Friction.

In a piece subjected to any system of loading, it is easy to show that at every point the direction of maximum shear is inclined at 45^0 to that of the maximum and minimum principal stresses, and that its value is one-half the algebraic difference of these stresses. In the foregoing, it has been shown that in some cases, where fracture is undoubtedly a shearing process, the surface of sliding is inclined to the direction of principal tension at an angle which differs somewhat from 45^0. One method of attempting to explain this discrepancy consists in postulating an internal resistance of the particles of the material to sliding one over the other, this resistance being of the nature of a simple friction. It results from such an assumption that the direction of sliding is inclined at $(45^0 + \varphi/2)$ to that of principal tension, and at $(45^0 - \varphi/2)$ to that of principal compression, if $\mu\,(= \tan\varphi)$ be the coefficient of internal friction. And the magnitude of the minimum internal resistance to sliding is,

$$\frac{1}{2}\left[p_1\left(\sqrt{1+\mu^2}+\mu\right) - p_3\left(\sqrt{1+\mu^2}-\mu\right)\right]$$

where p_1 is the principal tension, and p_3 is the principal compression, compressions being taken as negative.

On applying this method to the experimental results already obtained for steel, it was found that the coefficient of internal friction differed little from that of ordinary sliding friction for two separate pieces of steel. No definite assertion is made that the two coefficients are identical, and, in fact, the coefficient of internal friction is a mere assumption. But this close similarity was considered sufficiently remarkable to justify a few calculations, based upon a generalisation of this result, the results of which may prove interesting.

The Relation between the Yield Points of Steel when subjected to Pure Tension, Pure Compression, and Pure Shear.[1])

If yielding occurs when the minimum resistance to sliding within the piece is just overcome by the applied load, it follows

[1]) Proc. Roy. Soc. Edin., XXVIII, May 1908, 374.

hat for the same material under the three conditions of simple oading,

$$t\,(\sqrt{1+\mu^2}+\mu) = c\,(\sqrt{1+\mu^2}-\mu) = 2\,q\,\sqrt{1+\mu^2}$$

vhere t is the stress at the tension yield point, c that at the compression yield point, and q is the yield point of the material when ubjected to a simple, uniform shear. And taking $\mu = 0.14$ for teel, as given by Morin: $t = 0.76\,c = 1.76\,q$. Experimental results btained up till now have been somewhat variable, and are not n very close agreement with these figures. If strength is dependent ipon the magnitude of the maximum shearing stress, as is conended by some, the relation between the yield points is: $t = c = 2\,q$.

The Crushing Strength of Brittle Materials.[1])

Although a ductile material, when loaded in tension, gives vay usually by shearing along some oblique surface, it does not ail in this manner when subjected to a compressive force. On the ther hand a brittle substance, which, under a tensile load, would upture along a direction approximately normal to the stress, reaks, when crushed, by shearing obliquely. According to previous ssumptions, this sheared surface should be inclined at $(45^0 - \varphi/2)$ o the direction of compression.

An examination of some broken compression specimens of ast iron showed that the average inclination of the fractured surace was about 36^0, whereas it should have been about $40^1/_2{}^0$ if Morin's coefficient of sliding friction for cast iron, 0.16, be taken s $\tan \varphi$. But in a crushing test, the friction between the ends f the specimen and the plates of steel, or of cast iron, between vhich it is crushed, is not negligible, and must tend to increase he resistance of the piece. It will cause also an alteration in the nclination of the surface of shearing. The change in the slope of his surface can be found, upon the supposition that the frictional esistance to motion of the particles at each end of the specimen ipon the crushing plate acts as a force, at right angles to the compressive load, in such a manner as to hinder the separation of he block into two parts. Moreover, the increased resistance of he piece under test, due to this frictional force, can be calculated, f it be assumed that the yield point of a brittle substance is coincident with its breaking stress. Thus a figure may be obtained

[1]) Proc. Roy. Soc. Edin., December 1908.

for the ratio of the crushing stress as found in the ordinary test, to what may be called the true crushing strength of the material — that is, the strength which would be obtained if the end friction could be prevented by any means.

The value of this ratio is

$$\frac{c_0}{c} = \frac{\sqrt{1+\mu^2} - \mu}{\sqrt{(1+\mu^2)(1+\mu_0^2)} - (\mu + \mu_0)}$$

where c_0 is the compressive strength given by the test, c is the so-called true crushing strength, μ is the coefficient of internal friction, and μ_0 is the coefficient of friction between the ends of the specimen and the crushing plates. For cast iron the numerical value of this ratio has been calculated as 1·2 — in other words, cast iron, as tested, shows a crushing strength which i 20 per cent. too high. For materials like stones, bricks, and concrete, the results are remarkable. The ratio varies from 1·5 to 3·0, the higher values being obtained for the softer and coarser materials. This means that tests of such substances give figures which are from 50 to 200 per cent. too high.

So far, the writer has made no experiments to check these calculations directly. They need give rise to no alarm, of course, since the conditions of actual use are practically the same as the conditions of testing. An indirect check is afforded by measurements of the inclination of the sheared surfaces of the crushed blocks. According to the assumptions stated above, the angle of fracture should be $[45^0 - (\varphi + \varphi_0)/2]$, where $\tan \varphi_0 = \mu_0$. Actual inclinations agree very well with those calculated from this expression.

The same methods allow of the estimation of the weakening effect caused by the interposition of plates of lead, or of other soft material, when testing stones, but in this case there are effects other than those contemplated here.

Conclusions.

The general directions of internal sliding in a body under load, as revealed by the lines of Lüders and by fractured surfaces, are consistent with the action of a frictional resistance between the particles of the body, differing little from that of ordinary external frictional resistance.

Determinations of strength show variations far too great to allow of even an approximate calculation of the value of the coefficient of internal friction, and conversely, give unsatisfactory checks upon any calculations based upon an assumed coefficient. This suggests that the resistance of materials to stress is subject to other disturbing factors, the effects of which are at present unknown. The contractile cross is a visible effect of one such factor, which is operative at least upon thin, flat, metal bars.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS
Vth CONGRESS, COPENHAGEN 1909.

X 7

ETERMINATION OF THE SIMPLEST METHOD FOR 'HE SEPARATION OF THE FINEST PARTICLES IN ORTLAND CEMENT BY LIQUID AND AIR PROCESSES.

port of Committee 30. By Professor **M. Gary**, Gr.-Lichterfelde.
Translated by A. R. Liddell, Charlottenburg.
Together with a report by P. Mayntz Petersen, Copenhagen.

I laid a first proposal before the Budapest Congress that the ssociation should invite the testing establishments of the various ountries to study the problem of finding the simplest method r the separation of the finest particles in Portland cement by quid or air process.

The Association in acceding to this proposal, nominated me Reporter, and requested me to invite the public laboratories nd testing establishments to take part in the solution of the roblem.

I presented a report to the Congress in Brussels in 1906 on e results of my investigations and on the experiments of the önigliches Materialprüfungsamt of Groß-Lichterfelde. This report duced the Council at their meeting in the spring of 1907 to ominate a committee for the further treatment of the problem nd to appoint me as chairman.

The following gentlemen and establishments were included the Committee: Professor Mesnager, ingénieur en chef des onts et chaussées, Paris; Dr. A. Dickerhoff, Manufacturer, Amöne- rg near Biebrich on the Rhine; H. K. G. Bamber, Ingress House, reenhithe, Kent, England; Lejeune, Engineer of the Laboratoire

Pavin of Lafarge, Viviers (Le Teil), France[1]); Mayntz Petersen, of the State Testing Establishment, Copenhagen; The Eidgenössische Materialprüfungsanstalt, Zürich.

In a circular dated July 12, 1907, I supplied these members with a reprint of my report to the Congress in Brussels and with a copy of a paper which I read in February, 1907, before the Verein deutscher Portlandzement-Fabrikanten on the wind-sifting of finely-ground Portlandcement.

I further asked the members:

1. Whether they consider it necessary that fresh experiments be undertaken with the object of discovering a method for the determination of the finest particles, or

2. Whether they are prepared to make trial of the Gary-Lindner apparatus?

3. What alterations they propose in regard to the constuction of the apparatus and to the method of presentation of the results?

4. In case problem 1 be answered in the affirmative, what apparatus is recommended, and what experiments are considered suitable for joint conduct by the whole Committee?

The answers received were unfortunately for the most part not very satisfactory.

Mr. Lejeune died in the course of the year 1908. Professor Mesnager is of opinion that sufficient evidence has not yet been collected in regard to the practical value of any apparatus for the determination of the finest particles in Portland cement, and wishes that further investigations be made before the Members of the Committee proceed to try a particular apparatus.

To my communication to Mr. Bamber I have received no reply.

Dr. Dickerhoff and Professor Schüle have not yet found time to apply themselves to the problem, but Professor Schüle has obtained an apparatus in accordance with my proposal.

Mr. Mayntz Petersen has continued the experiments which he began some years ago with his own apparatus, and makes a report on these which will be found in the appendix.

To the experiments carried out by Mr. Mayntz Petersen the objection may be made, that they take the place only of a

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1) Since then, R. Feret has been nominated instead of the late Mr. Lejeune

sieve finer than 5000 meshes to the square centimeter, and separate the cement undergoing test into only two parts (fine and coarse meal), but that in the case of different cements with obviously very different graining it shews only small unadvantageous differences from the separation by means of the 5000-mesh net.

According to Table I (see appendix) the 16 cements tried on the 5000-mesh net gave a residue of 8,0 to 25,0 %; in the case of wind-sifting the differences vary between 40,2 and 57,3 %. As shown by Fig. I, the results obtained by the two methods

Sifting Experiments with Cements according to Mayntz Petersen.

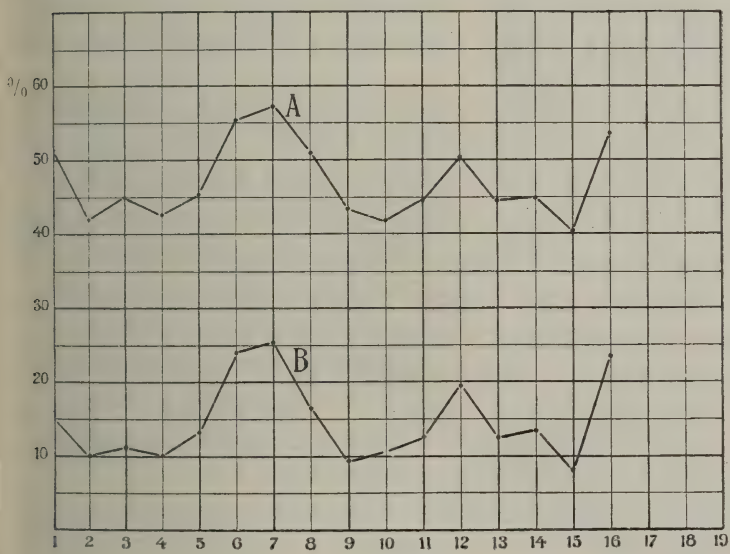

Fig. I.

A. Wind-Sifting according to Mayntz Petersen; B. 5000-Mesh Sieve.

run almost parallel. From these wind-sifting experiments, then, no new distinguishing characteristics for the Portland cement are obtained, and above all it is not apparent, in what relation the grains of the finest parts of the cement stand towards eachother.

The wind-sifter proposed by me avoids these short-comings, as I was able to show in a paper read before the Verein deutscher Portlandzement-Fabrikanten on Feby. 20, 1907.

Mr. Mayntz Petersen on the other hand is of opinion tha since, on account of defects of manufacture,the 5000-mesh siev gives very unreliable results and leaves so little residue behin that the sifting results present only an imperfect picture of th fineness of the meal, his apparatus constitutes a step in advanc and satisfies the conditions of the problem of the finding of uniform method for the determination of the finest particles i Portland cement.

In the following I shall again give a short account of m apparatus with the remark that new experiments have not in th meantime been carried out because it was desired that the opinion of the other members of Committee 30 should first be obtained That the time given for this would pass almost without result could not be foreseen.

When in 1887 the "Prussian Standards for the Delivery o Portland Cement" laid down tbe condition: "Portland cement shal be so finely ground that a sample of it on a sieve of 900 meshe to the sq. cm. leaves a residue of at most 10%" many manufactories were obliged to improve their grinding and siftin apparatus in order to fulfil it. It soon appeared, however, tha the cement-mills were making great improvements. Most of th cements of commerce left residues of only a few per cent on th 900 sieve, and, in order the better to show the grinding, the siev with 4900 meshes to the sq. cm. — the so-called "5000-mes sieve" — was introduced. I have already given demonstration o the inaccuracies that attach to this sieve.[1])

Meanwhile entirely new paths have been opened to the cement-grinding industry by the introduction of the Griffin mill, the tub mill, and other apparatus, and it may safely be asserted that fe Portland cements now leave more than 25% residue on th 5000-mesh sieve. 75% or more of the meal thus falls through th finest of the sieves used to characterize the grinding, and canno be further judged.

Now it is a matter of common knowledge that a hydrauli cement is the more effective and can be made the more of, th more finely it is pulverized. Fine grinding, however, meets wit technical difficulties and is expensive. The manufactories consequentl

[1]) Gary: Sand- und Cementsiebe. Mitteilungen aus dem königl. Materia prüfungsamt 1896, page 294.

ave an interest in shewing what degree of fineness their finest ıeals attain, and in making this clear to the users.

Starting from this idea, experiments have been instituted in ıe königl. Materialprüfungsamt of Gross-Lichterfelde, which, after ıe complete working out of the method, seem to have led to the esired result.

The Gary-Lindner apparatus, with which these experiments vere carried out (see Fig. II), delivers, within a few minutes and vithout any previous preparation r subsequent drying of the maerials, four fractions of the parcles, which are not indeed sorted ntirely according to size of grain, ut which nevertheless establish haracteristic marks of difference or the various cements.

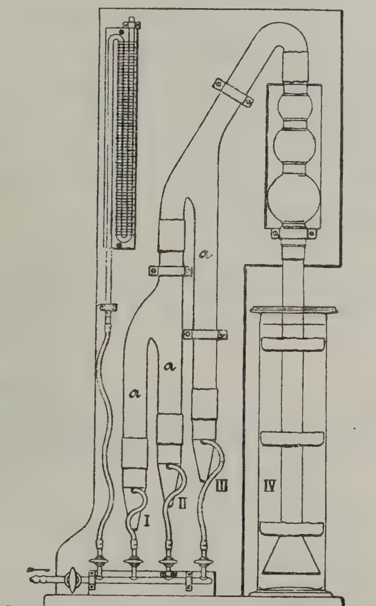

Fig. II.
Wind-Sifter on the Gary-Lindner Plan.

The apparatus consists of ıree wide glass tubes connected vith each other at their lower ends y india rubber sleeves ending ı glass funnels into which are ıelted little glass tubes reaching early to the ground for the ıtroduction of air. Into the rst funnel, No. I, are introduced 0 grs. of the previously dried owder that is to be tested, fter which compressed air at pressure of 100 mm of waterauge is blown in. Glass cocks ender possible the adjustment of the air-pressure for each funnel; ıe pressure is read from a U-shaped manometer. The funnels I, II, nd III are set to work in succession. In each of these a fractional uantity of the powder finally remains behind, and the fine ıaterial leaves the end of the third glass in the form of dust and caught in the wide glass vessel No. IV.

When the compressed air is produced by water-jet blowers, has to be dried before its entrance into the funnel — e. g. by ıe insertion of a Woulff's bottle of sulphuric acid.

In the report of Committee 30, which I laid before the Congress of the Association in Brussels in 1906, a few lines of the tables of results are given, which in particular show the characteristic differences between different kinds of cement. At that time, however, we had not succeeded in spreading the powder on an object-bearer with sufficient evenness to enable it to be photographed. This can now be done without difficulty, as may be seen in Fig. IV. The results of a few further experiments are given in Tables B and C.

Table A gives the general properties of four cements, on which the tests were made, Table B the test-results of these four cements, viz. of three Portland cements a, b, and c, and a ferro-Portland cement d, in the original condition of the materials, and Table C the results of the wind-sifting of the fine meal portion of this cement which has fallen through the 5000-mesh sieve.

Fig. III gives the granulometrical properties of Cement d (a ferro-Portland cement) which was separated in the original condition on the wind-sifter. The four grain-distribution pictures

Table A. Properties of the Cements used in the

Cement Mark	Specific gravity of the ignited Cement Powder	Loss of Cement Powder in the Heating	One Litre of Cement weighed		Water in pure Cement		300 grs. of Cement mixed with the given Quantity of Water gave		Averages during the Determination of the Time of Setting		
			run in	shaken in	for treacle-like Consistency	for the Setting Test	Time of Setting a) Beginning b) Completion of the Hardening	Increase of Heat in Setting	Temperature of the Air	Temperature of the Water	Moisture of the Air
		%	kgs.	kgs.	%	%	Hours	C.°	C.°	C.°	%
a	3·218	0·56	1·196	2·015	35	26	6 8^{30}	2·5	16·0	13·2	75
b	3·242	2·43	1·230	2·005	34·5	25·5	7^{15} 10^{45}	0·3	17·0	15·0	59
c	3·110	1·98	1·118	1·857	37·0	28·0	6^{15} 12	1·7	16 0	13·8	70
d	3·077	7·87	1·035	1·759	33·0	27·0	1 4	1·8	17 8	17 5	80

are given side by side at the bottom of the figure considerably enlarged. Each of the fields enclosed by the white lines represents 1/16th. of 1 mm². (Fig. IV comprises a surface of 1 mm² divided into 16 squares in 80-fold enlargement).

In Fig. III, above each field representing a grain-distribution, an ordinate is given, which is equal to the number of the grains in question in hundredths, so that the line of the curve through the end-points of these ordinates gives graphic delineation of the composition of the cement as regards coarse and fine grain.

The results of the sifting of the cement on the 5000 (1), 900 (2), 600 (3) and 324 (4) mesh nets respectively are set off in the upper right-hand corner of Picture 3. The ordinates here represent the quantities of the residue left on the respective sieves.

Results differing considerably from the foregoing are obtained if the cement be first sifted on the 5000-mesh sieve and the finest meal that has fallen through the latter be then treated with the wind-sifter (Fig. V).

A cement would give evidence of the most favourable degree of grinding for the exercise of its binding power if the line con-

Experiments with the Wind-Sifter.

Test of Constancy of Volume as compared with Standards	Residue on 5000 Meshes to the sq. cm. 1 %	Residue on 900 Meshes to the sq. cm. 2 %	Residue on 600 Meshes to the sq. cm. 3 %	Residue on 324 Meshes to the sq. cm. 4 %	Residue on 120 Meshes to the sq. cm. %	1 Part Cement and 3 Parts Standard Sand by Weight: Water in Mortar Samples %	Tensile Tests, Area of Fracture = 5 sq. cm.: Tensile Strength kilogrammes per sq. cm. 7 Days	Tensile Strength kilogrammes per sq. cm. 28 Days	Apparent Specific Gravity G/Jm	Compression-Tests, Area of Compress. = 50 sq. cm.: Compress. Strength kgs per sq. cm. 7 Days	Compress. Strength kgs per sq. cm. 28 Days	Apparent Specific Gravity G/Jm
good	21·6	5·2	3·8	0·8		8·5	23·5	28·1	2 286	230	314	2·239
good	24·0	1·7	1·0	0·2		8·75	13·0	16·6	2·286	88	134	2·231
good	7·9	0·6	0·6	0·2	0·2	8·25	10·0	22·0	2·300	77	174	2·225
good	16·0	0·4	0·2	0·0		8·75	21·9	25·5	2·286	151	182	2·314

Table B. Tests on Four Cements in their Original Condition.

Cement	No. of Test	Time in Minutes	Pressure in mm	Residue in Vessel No. grs. I	II	III	IV
a	1	20	100	7·75	4·47	2·90	4·88
	2	20	100	7·72	4·64	2·30	5·34
	3	20	100	7·80	4·77	2·42	5·01
	Mean		grs.	7·76	4·63	2·54	5·07
			%	**38 9**	**23·2**	**12·7**	**25·2**
b	1	20	100	9·15	4·12	1·80	4·93
	2	20	100	9·60	3·88	1·92	4·60
	3	20	100	9·74	3·77	1·88	4·61
	Mean		grs.	9·50	3·92	1·87	4·72
			%	**47·4**	**19·6**	**9·3**	**23·6**
c	1	20	100	6·70	5·28	2·42	5·60
	2	20	100	6·96	5·00	2·18	5·86
	3	20	100	6·82	5·14	2 30	5·74
	Mean		grs.	6·83	5·14	2·30	5·73
			%	**34·2**	**25·7**	**11·5**	**28·6**
d	1	20	100	8·05	4·07	2·15	5·73
	2	20	100	7·72	4·43	2·05	5·80
	3	20	100	7·80	4·37	1·82	6·01
	Mean		grs.	7·86	4·29	2·01	5·85
			%	**39·3**	**21·4**	**10·1**	**29·3**

Table C. Tests on the Finest Meal in Four Cements (5000-Mesh Sieve).

Cement	No. of Test	Time in Minutes	Pressure in mm	Residue in Vessel No. grs. I	II	III	IV
a	1	20	100	3 52	7·20	2·80	6·48
	2	20	100	3·87	7·22	2·99	5 92
	3	20	100	4·25	6·62	2·89	6·24
	Mean		grs.	3·88	7·01	2·89	6·22
			%	**19·4**	**35·0**	**14·5**	**31·1**
b	1	20	100	4·57	7·20	2·52	5·71
	2	20	100	4·93	7·15	2·61	5·31
	3	20	100	4·64	7·07	2·38	5·91
	Mean		grs.	4·71	7·14	2·50	5·60
			%	**23·6**	**35·7**	**12·5**	**28·2**
c	1	20	100	3·03	7·95	2 44	6·58
	2	20	100	3·18	7·75	2·65	6·42
	3	20	100	3 10	7·86	2·48	6·56
	Mean		grs.	3·10	7·85	2·52	6·52
			%	**15·5**	**39·3**	**12·6**	**32·6**
d	1	20	100	4·37	6·68	2·35	6 60
	2	20	100	4·35	6·58	2·42	6·65
	3	20	100	4 95	6·10	2 42	6·53
	Mean		grs.	4·56	6·45	2·40	6·59
			%	**22·8**	**32·7**	**12·0**	**32·9**

necting the ordinates should take the form of a branch rising fro[m] left to right, or if this line lay horizontal.

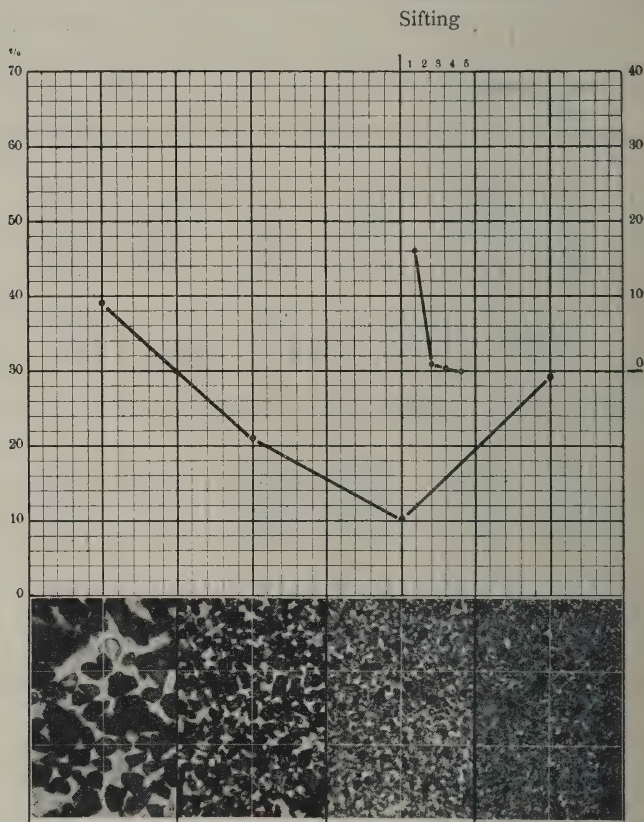

Fig. III.

Observations: Under „Sifting",		1 means the sieve with				5000 meshes to 1/9				
„	„	2	„	„	„	„	900	„	„	„
„	„	3	„	„	„	„	600	„	„	„
„	„	4	„	„	„	„	324	„	„	„
„	„	5	„	„	„	„	120	„	„	„

The ordinates set off above the grain-distribution pictures give the numbe[r] of grains corresponding with each picture of the four fractions of the ceme[nt] separated in its original condition by the wind-sifter.

The ordinates of the small curves at the upper right-hand corner deno[te] the amonts of the residues left between every two consecutive sieves.

It will be seen that fairly correct pictures of the granulometric omposition of a cement may in this way be obtained and that : may also perhaps be possible, in using one and the same naterial as a basis, to give pictorial representation of the action of different grinding-apparatus.

Finally, chemical analysis, applied to the four fractions, also rovides a means for the detection of foreign substances in the ement.

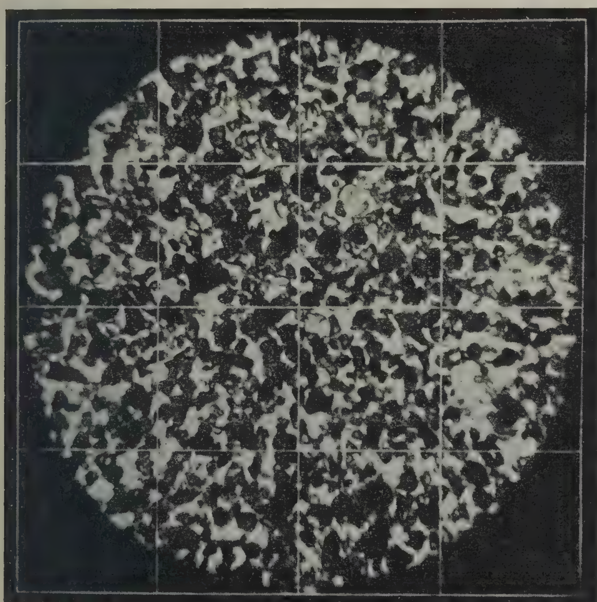

Fig. IV.

1 mm² Ferro-Portland Cement Dust in 80-fold enlargement.

Investigations of the kind described can now be carried out o order with the wind-sifter in the Materialprüfungsamt at Gross-ichterfelde West at a moderate charge.

It is beyond all doubt that manufacturers and users, as soon s they have recognised the great advantages of the new method, vill avail themselves extensively of it.

The question as to which method and apparatus is to be preferred — the somewhat simpler Mayntz Petersen apparatus, an experiment with which separates the meal into two parts, or the Gary Lindner apparatus which separates it into four parts — will

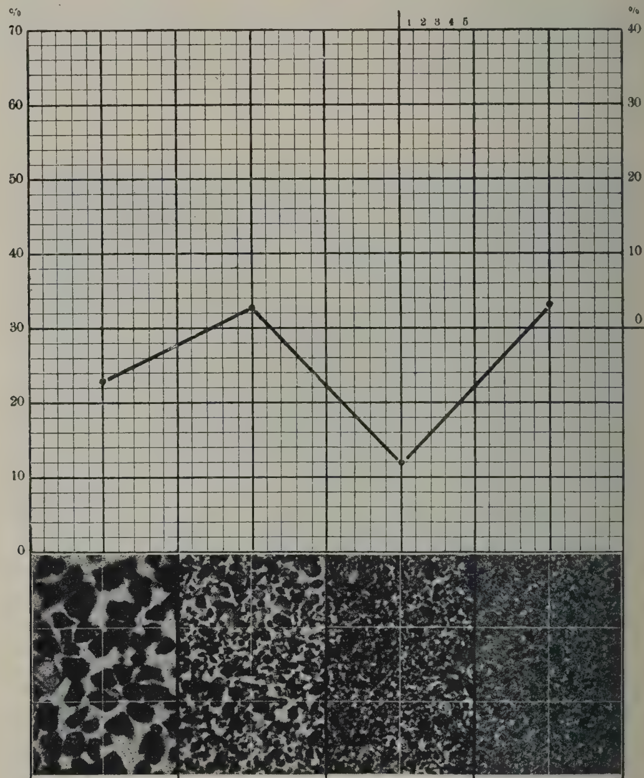

Fig. V.

Ferro-Portland Cement per cent on 5000-Mesh Sieve.

indeed have to be left for the decision of the Committee or of the Congress. Both apparatus are serviceable. The one last mentioned may be obtained from the Chemisches Laboratorium für Tonindustrie, Berlin N. W. Dreysestraße 4, or from the firm of C. Richter, Berlin, N., Johannesstraße 14/15.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

V[TH] CONGRESS, COPENHAGEN 1909.

X 8

DETERMINATION OF THE SIMPLEST METHOD FOR THE SEPARATION OF THE FINEST PARTICLES IN PORTLAND CEMENT BY LIQUID AND AIR PROCESS.

Appendix to the Committees Report by **Mayntz Petersen**, Copenhagen.

Translated by A. R. Liddell, Charlottenburg.

The experiments begun in 1903 for Committee 30 of the "International Association for Testing Materials" for the determination of the finest particles in Portland Cement, in regard to which a preliminary report has already been presented to the Brussels Congress, have now been completed. The Association of Scandinavian Portland Cement Manufacturers has with obliging readiness undertaken the defrayal of the expense connected with the experiments.

A current of air was used for the experiments, since it was assumed that the use of fluids would not be desirable. Water cannot be used for the levigation of cement, and the use of other fluids which do not attack this material would make the levigation very expensive. Preference was accordingly given to levigation by means of air and to the use of an apparatus similar in form to Schöne's levigating-funnel for the operation. Since, in view of the greater mobility of the air, jerky alterations of the air-current were expected, the cylindrical part of the funnel had to be made considerably longer, so that on the occurrence of the jerks the cement should not be thrown out of the funnel.

The experiments were at first made with a funnel, the cylindrical part of which was about 30 cm long and about 10 cm in diameter.

The levigating-funnel was connected with the pipe of a centrifugal blower by means of a rubber tube. In addition a pressure gauge was inserted in the air-tube by means of a branch pipe, so that the uniformity of the air-current at the different experiments could be checked.

A number of preliminary experiments were made with this levigating-funnel in the following manner. The funnel was connected with the air-tube, and the air valve opened, and 5 g of cement introduced through a copper funnel into the glass funnel. A larger quantity of cement could not be made use of, because the lower opening of the levigating-funnel then became choked.

Figure 1.

At the conclusion of this experiment the air-current was shut off and the residue of the material removed from the levigating-funnel and weighed.

These preliminary experiments are described in greater detail in the report to the Brussels-Congress.

The shape of the levigating-funnel being somewhat unsatisfactory, inasmuch as its lower part was not conical but was rather suddenly narrowed-in below the cylindrical part, another one of more suitable form was obtained. This is shown in Fig. 1.

With this funnel the experiments were made in the same manner as with the one above mentioned. Investigation was first made as to the time taken by the levigation until no more dust was carried forth. Since it was here established that after the lapse of 15 minutes the quantity of material left in the funnel ceased to be appreciably reduced, a 15-minute time of levigation was made use of in all the succeeding experiments. In order to make sure that no more material is carried forth, an incandescent lamp is held behind the funnel; even small quantities of dust can then be detected in the air-current.

A microscopical examination showed the limit of the size of grain between the residue in the levigating-funnel and the

owder carried forth from it to lie at a minimum diameter of bout 0·03 mm.

Finally levigation experiments were made with the same evigating-funnel on 16 different cements, which were taken from he cement investigations in progress at the State Testing Establishnent. At least two experiments were made with each cement The results are given in Table I.

It will be observed from the figure in Table I hat the various experiments with the same cement ave given results agreeing very well together. When a somewhat greater difference shows itself in some of the experiments, as for instance in Nos. 1, 2, 3, and 16, the cause of this is probably to be found, not in irregularities of the method, but in the circumstance that there is really a difference between the samples in question. The observation was in fact made in the course of the experiments, that when extreme care was taken in mixing, before the levigation of the cement from which the samples were taken, two different levigations gave results which agreed with one another almost exactly.

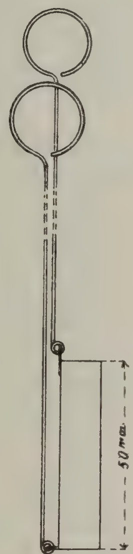

Figure 2.

From the Experiment No. 4 onward the cement was introduced into the funnel by a method differing from that previously applied. The cement was weighed out in the little cylindrical brass receptacle (shown in Figure 2), to which the thin brass wires observable in the illustration were then attached.

The air-current being then set in motion, the receptacle was lowered through the upper opening into the levigating-funnel and kept turning by the help of the brass wires until the cement fell out. When completely emptied, the receptacle was drawn up as quickly as possible through the opening. No cement dust showed itself in the air-current at the upper opening of the levigating-funnel till the receptacle was clear of the funnel.

In the case of several of the experiments given in Table I the residue which remained in the levigating-funnel and also samples of the dust were examined with the microscope in order to determine whether the former was freed of all grains of less than 0·03 mm in diameter and to make sure that no grains of

Table I.

Number of Experiment	Weight of the Cement used for Levigation	Duration of the Levigation	Residue in the Levigating-Funnel		Residue on a Sieve with 5000 Meshes to the sq. cm	
	grs.	Minutes	grs.	%	grs.	%
1 a	5·000	15	2·606	52·1	0·759	15·2
1 b			2·536	50·7	0·733	14·7
2 a	5·000	15	2·070	41·4	0·558	11·2
2 b			2·131	42·6	0·546	10·9
3 a	5·000	15	2·214	44·3	0·543	10·9
3 b			2·282	45·6	0·573	11·5
4 a			2·132	42·6	0·506	10·1
4 b	5·000	15	2·144	42·9	0·513	10·3
4 c			2·108	42·2	0·511	10·2
5 a	5·000	15	2·286	45·7	0·627	12·5
5 b			2·238	44·8	0·696	13·9
6 a	5·000	15	2·789	55·8	1·200	24·0
6 b			2·756	55·1	1·218	24·4
7 a	5·000	15	2·850	57·0	1·284	25·7
7 b			2·879	57·6	1·264	25·3
8 a	5·000	15	2·554	51·1	0·839	16·8
8 b			2·539	50·8	0·834	16·7
9 a	5·000	15	2·167	43·3	0·472	9·4
9 b			2·176	43·5	0·462	9·2
10 a	5·000	15	2·114	42·3	0·569	11·4
10 b			2·087	41·7	0·518	10·4
11 a	5·000	15	2·229	44·6	0·640	12·8
11 b			2·237	44·7	0·626	12·5
12 a	5·000	15	2·525	50·5	0·990	19·8
12 b			2·520	50·4	0·990	19·8
13 a	5·000	15	2·223	44·5	0·635	12·7
13 b			2·206	44·1	0·610	12·2
14 a	5·000	15	2·250	45·0	0·669	13·4
14 b			2·251	45·0	0·670	13·4
15 a	5·000	15	2·013	40·3	0·398	8·0
15 b			2·012	40·2	0·398	8·0
16 a	5·000	15	2·726	54·5	1·178	23·6
16 b			2·640	52·8	1·178	23·6

·eater diameter than 0·03 mm were contained in the dust that as blown away. It transpired that only an inconsiderable quantity ' the grains were not properly sorted by the levigation.

The material required for these and for the previously mentioned icroscopical investigations of the dust was obtained by holding piece of filtering-paper above the upper opening of the levigating-.nnel. On this a quantity sufficient for the investigation always eposited itself. Since this method of obtaining the material did ot always ensure that grains of greater diameter than 0·03 mm ere not drawn along with the finer particles the following check-xperiment was made.

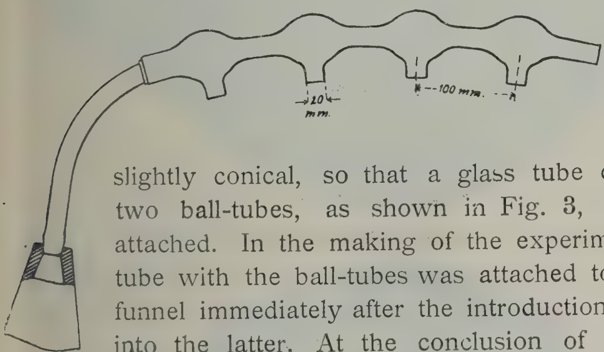

Figure 3.

The opening at the upper end of the levigating-funnel was ground slightly conical, so that a glass tube connected with two ball-tubes, as shown in Fig. 3, could here be attached. In the making of the experiment the ground tube with the ball-tubes was attached to the levigating funnel immediately after the introduction of the cement into the latter. At the conclusion of the experiment the quantities of powder which had collected in the various swellings of the ball-pipes were taken out and eparately examined with the microscope.

It here appeared that the powder caught in the ball-pipes, ven in the swelling nearest to the levigating funnel, contained nly a very few solitary grains larger in diameter than 0·03 mm, s may be seen from the accompanying Fig. 4 and 5.

Fig. 4 represents a micro-photograph of the powder which ad collected in the tube-swelling next the levigating-funnel. For omparison, two micro-photographs (in the same enlargement) are iven, taken from preparations of the portion of material which ad remained behind in the levigating-funnel at Experiment No. 1, onsisting in the one case of the fine powder which in the sifting rocess had passed through the sieve with 5000 meshes to the q. cm. (see Fig. 5), and in the other of the residue which emained behind on this sieve (Fig. 6).

After the completion of the above-mentioned experiments various alterations were made in the apparatus. Fig. 7 shows

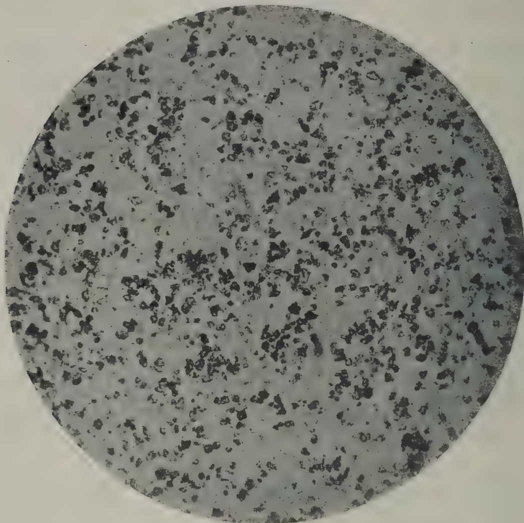

Figure 4.

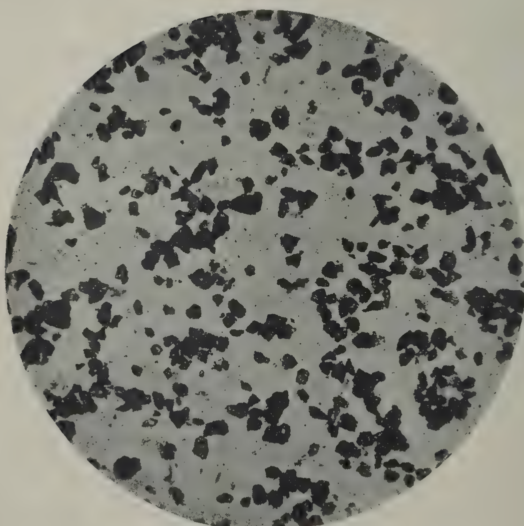

Figure 5.

the general outline of the apparatus in its altered form. The air enters at a, passes through the cock-piece h, the rubber tube d,

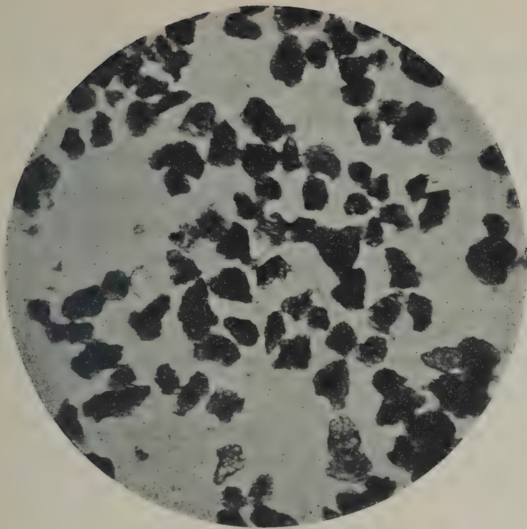

Figure 6.

the bent glass tube e, and the rubber tube f, up into the funnel T, where the levigation takes place. The cock-piece is situated at the lateral tube g with the cock c in connection with the pressure gauge m. The sections of the tubes b and c are of the same diameter as the clear opening in the corresponding glass tubes, so that the air meets with no resistance. By means of the cock b the air current can be effectually and quickly cut off, when the residue is to be removed from the funnel after the levigation. Oil of turpentine, which is sufficiently mobile, is applied in the pressure gauge.

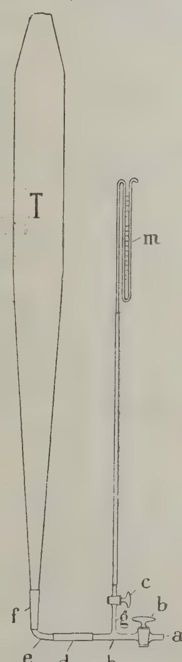

Figure 7.

As already mentioned, the air-current required for the experiments is produced by means of a centrifugal blower, which is placed in connection with the cock-piece h by means of a rubber tube. A slide-valve is inserted directly in front of the rubber tube, by means of which the air-current can be regulated so that a constant height of pressure can be maintained in the pressure gauge.

Table II, given below, contains the results of levigation experiments made with 6 different cements. The experiments were made with the funnel shown in Fig. 1, fitted up in the manner shown in Fig. 7.

In connection with the experiments hitherto mentioned it had always transpired that uniform results had been obtained in the process of

levigation when the latter was repeated with the same cement, and that the separation between the particles removed by the process and the residue in the funnel took place at a certain particular size of grain. It remained to be investigated, whether it was a matter of comparative ease so to adjust different funnels that they would give the same result with the same cement. For these investigations 3 new funnels were obtained. These are marked below as Numbers II to IV, while the one previously mentioned is marked No. I.

Table II.

No. of the Cement	Height of Pressure in the pressure gauge	Weight of Cement used in the Levigation	Duration of the Levigation	Residue in the Levigating Funnel		Mean Result from the two Experiments
	cm	grs.	Minutes	grs.	%	%
2099	7·3	5·000	15	2·077	41·5	41·4
	7·2	5·000	15	2·066	41·3	
2102	7·3	5·000	15	2·697	53·9	54·0
	7·4	5·000	15	2·704	54·1	
2103	7·2	5·000	15	2·468	49·4	49·5
	7·3	5·000	15	2·482	49·6	
2106	7·4	5·000	15	2·246	44·9	44·8
	7·2	5·000	15	2·231	44·6	
2117	7·4	5·000	15	2·372	47·4	47·5
	7·4	5·000	15	2·373	47·5	
2119	7·2	5·000	15	2·401	48·0	47·9
	7·3	5·000	15	2·388	47·8	

The remaining properties of the cement may be seen in Table III.

So far as could be managed, Funnels II to IV were made of the same shape and dimensions as Funnel I, and their upper openings were ground in such a manner that their diameters were the same as that of the latter, i. e. equal to about 22 mm.

Table III.

No. of the Cement	Time of Setting (Hours)	Residue on a Sieve with 900 Meshes per sq. cm.	2500	5000	Strength in kgs. per sq. cm. of the Test-Sample of 1 Cement + 3 Standard Sand after 3 Days: Tension	3 Days: Compress.	7 Days: Tension	7 Days: Compress.	28 Days: Tension	28 Days: Compress.
2099	$6^3/_4$	0·4	8·3	11·1	16·9	133	21·0	203	26·4	333
2102	$7^1/_2$	2·3	20·2	25·8	16·2	106	18·7	206	24·9	318
2103	11	2·5	16·1	19·8	4·2	41	6·9	68	17·8	158
2106	$7^3/_4$	0·2	7·5	12·7	17·7	145	28·1	284	33·8	497
2117	7	0·5	11·2	16·3	16·1	111	21·2	202	26·1	318
2119	$6^1/_4$	0·6	13·5	17·5	12·3	96	13·8	135	16·8	209

After this the lower end was drawn out to a point, and by the breaking or grinding off of the material of this point it was found possible without much trouble so to adjust the three funnels that they gave the same result as Funnel I.

Table IV.

No. of Funnel	Height of Pressure in the pressure gauge (cm)	Weight of the Cement used in the Levigation (grs.)	Duration of the Levigation (Minutes)	Residue in the Levigating Funnel (grs.)	Residue in the Levigating Funnel (%)	Mean of the two Experiments (%)
I	7·2	5·000	15	2·314	46·3	46·3
	7·3	5·000	15	2·315	46·3	
II	5·3	5·000	15	2·333	46·7	46·2
	5·3	5·000	15	2·278	45·6	
III	5·5	5·000	15	2·304	46·1	46·2
	5·5	5·000	15	2·314	46·3	
IV	5·2	5·000	15	2·312	46·2	46·2
	5·1	5·000	15	2·312	46·2	

Table IV contains the results of levigation tests with the same cement in Funnel I as well as in Funnels II to IV after the adjustment had been effected.

It will be seen from these tests that it is possible so to adjust different funnels that they give the same results as a single standard funnel.

XI 1

EXPERIMENTS ON THE DECOMPOSITION OF MORTARS BY SULPHATE WATERS.

By **J. Bied,** Le Teil (Viviers, Ardèche).

Translated from the French by Dr. H. Borns, London.

I. The decomposition of mortars, which are exposed to the action of the sea or of waters charged with sulphates, has for a long time already occupied the attention of engineers, and experiments have been multiplied in all quarters with the object of discovering some hydraulic binding material which would be free from liability to destruction.

Up till recent years attention has chiefly been concentrated on the injurious action of the sea water, and although the destructive effect of sulphate of lime was not unknown, it was not as a rule taken into consideration.

Having had to enquire into decompositions of mortars by sulphate of lime, observed in 1900 on the line leading from Linarez to Almeria in Spain, and in 1902 on the line St. Girons-Foix and at the same time in Algeria, we have been induced to submit this problem to a prolonged experimental investigation in the Laboratories of the Société J. et A. Pavin de Lafarge.

Although the first of these researches date back six years already, we consider them quite incomplete still, and if we have resolved to draw certain conclusions, it is because it appears that interesting information can already be deduced.

One of the particular results is the rehabilitation of an artificial puzzolana mentioned already by the celebrated Vicat; it had

fallen into complete oblivion, possibly on account of the difficulties of its manufacture.

In order to secure rapid results, we have tested some meagre mortar (one-fourth or fifth part by weight of cement, the rest sand) prepared with very fine sand (from the dunes, less than 0,5 mm) and immersed in very concentrated solutions: saturated solution of sulphate of calcium and a 12 per mille solution of anhydrous magnesium sulphate.

In addition to these solutions we commenced, two years ago, to experiment with artificial sea water.

To this sea water we have given the following composition:

sodium chloride	30 grammes	in 1 litre of water
crystallised magnesium sulphate	6 „	
magnesium chloride hydrated	6 „	
sulphate of lime hydrated	2 „	
Bicarbonate of potassium	2 decigrammes	

The plan on which we worked was the following:

The mortars were gauged to a plastic consistency and moulded in cubes of 50 cm^2 surface. The cubes were exposed for 24 or 48 hours maximum to the dry air, then taken out of the moulds, and either at once immersed in the solution under enquiry, or first immersed in flowing river water, in which they were kept for a month, protected against carbonatation, before being placed in the respective decomposing solution.

It should be noted that the cubes thus preserved for one month should not become carbonated, and that it is not astonishing to find that in certain cases, contrary to what was known, the liability to decomposition had been increased by not immersing the cubes at once.

The specimens were dipped into the solution under enquiry up to two-thirds of their height, and the basins were kept in a room whose temperature was maintained at 17 or 18^0 C., a temperature which facilitated the filtration and the evaporation of the saline solutions through the top of the cubes.

We should have liked to conduct regular chemical analyses, referred to the volume of the mortar and not its weight, as proposed by Mr. Maynard; but the necessary time and assistance were not at our disposal.

II. In our researches we have compared materials poor in alumina and aluminiferous mortars, highly calcareous mortars and some of high index.[1])

We have studied the behaviour of artificial puzzolanas and accessorily the action of calcium stearate which increases the impermeability of the mortars considerably.

The puzzolanas tested were:

1. A product obtained by fusion, granulated in cold water.

2. A kaolin clay, medium refractory (on account of its contents of iron) and dehydrated.

As early as 1846 Vicat had described the properties of calcined clay at length; he had even given a description of an apparatus for carrying this operation out practically (Nouvelles Études sur les Pouzzolanes Artificielles comparées à la Pouzzolane d'Italie). He estimated the appropriate calcination temperature at about 1000^0 C.

At present we know from the work Mr. Vogt on clays that the operation of calcination consists in dehydrating the kaolinit $2\ SiO_2 . Al_2O_3 . 2H_2O$, which is a constituent of all clays. This kaolinit, Vogt has shown, is attacked in the crude state by boiling sulphuric acid, but resists the acid, when it has previously been baked. Heated merely up to its dehydration temperature, which lies at about 700^0 C., it remains attackable by diluted hydrochloric acid.

This property of the dehydrated clay explains the puzzolanic action of the latter; it is unnecessary further to insist upon this point.

It will be understood that since kaolinit alone assumes puzzolanic properties by calcination, it is of importance to choose a clay which is as rich in kaolin as possible in order to avoid the introduction into the cement of feldspars which are always inert materials.

It should also be emphasised that the operation of dehydration is industrially a very delicate operation; if the desired temperature is not exactly realised, we may, by exceeding as well as by not reaching the proper calcination heat, manufacture an inert material instead of a puzzolana.

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[1]) The French 'indice' or hydraulic modulus here meant is the ratio: $(SiO_2 + Al_2O_5) / (CaO + MgO)$.

It is probably these two difficulties which explain, why the properties of the dehydrated clay have so long been disregarded.

We hasten to add that the puzzolanas, of whatever kind they may be should, in order to be active, always be most finely triturated and powdered, as far as possible, together with the cement itself in the trituration apparatus.

III. The action of the diverse saline solutions which were employed is not altogether the same. It may in general be assumed that the artificial sea water is 10 or 15 times less active than a 12 per mille solution of magnesium sulphate. Yet certain artificial cements have been decomposed more rapidly in sea water than in the solution of anhydrous magnesium sulphate.

The saturated solution of sulphate of calcuim is at least as destructive as the 12 per mille solution of anhydrous magnesium sulphate. But its effect appears to be different, sometimes more energetic, sometimes less energetic than that of the magnesium sulphate solution of 12 per mille.

IV. Water saturated with sulphate of lime appears to be the most active decomposing agent.[1]) Constructors must constantly be on the alert in this respect. In fact, waters saturated with calcium sulphate are sometimes met with far from any recognised occurrence of gypsum. [2])

On the other hand, waters which, at certain moments, do not contain more than 0·1 or 0·2 gramme of calcium sulphate may become saturated during periods of drought.

In our laboratory and under the experimental conditions above indicated, we have not met with any slow- or quicksetting cement, whatever its mode of manufacture and its chemial composition, which has resisted the action of this solution for six years (compare photograph 2).

Limes, even the least aluminous and of the best reputation as regards sea water, are rapidly decomposed.

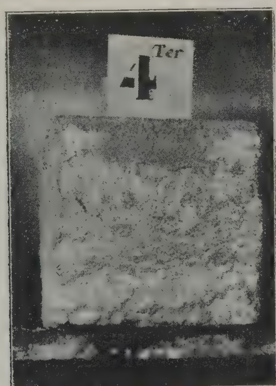
Quick-setting cements, of high index (compare footnote above), which had resisted for a long time, have commenced to display

[1]) The use in mortars of gypsiferous sands, particularly when fine, presents the same dangers.

[2]) Examples: the plains of Boufarik, the plains of the environments of Rouen, the sub-soil of Boulogne-sur-Mer.

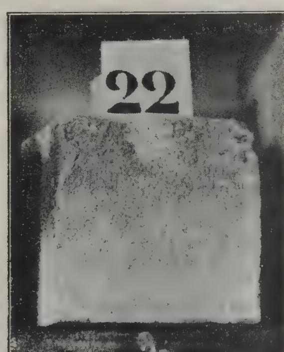
Finely ground silicious cement after 6 years in the saturated calcium sulphate solution.

Silicious cement treated with calcium stearate after 46 months in the saturated calcium sulphate solution.



Silicious cement of very high index after 6 years in the saturated calcium sulphate solution (superficial decompositions).

Cement 3^{ter} mixed with slag after six years in the saturated calcium sulphate solution.



Cement 3^{ter} mixed with clay after six years in the saturated of calcium sulphate solution.

signs of decomposition at the end of five years, and these decompositions appeared to deteriorate rapidly.

The addition of stearate of lime which renders the mortars more impermeable has proved insufficient to prevent the decomposition (compare photograph 77).

The augmentation of the index by silica has in itself not been sufficient either to prevent all decomposition, although some interesting results have been obtained (see photograph 4).

The puzzolanas have always had a notable ameliorating effect. The artificial slag appears more active from the start and imparts to the product a higher resistance than the addition of clay does; but its effect is less reliable and much less regular than the action of calcined clay, which seems to be the most energetic of all the puzzolanas (compare photographs 32, 2, 23).

The influence of the date of the immersion, after preservation of the cubes in flowing water, has shown sometimes in one sense, sometimes in another, for pure cements as well as for those mixed with puzzolanas.

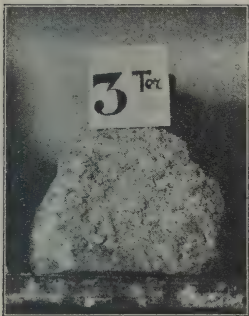
The quantity of the gauge water has been without influence on the decompositions, at least of those products to which puzzolanas had been added.

Finally we have crushed some cubes of pure cement and of cements to which puzzolana had been added. The best resistance values were obtained with mixtures of silicious cement and dehydrated clay in the proportion of one part of cement to one part of clay.

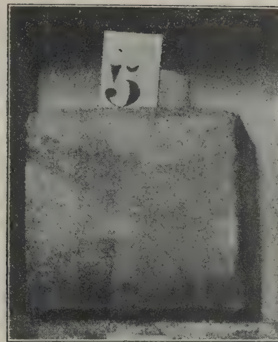
It may prove possible to reduce, in these cements, the proportion of clay to two parts of cement for one part of clay. But we do not possess experience of sufficient length to speak with certainty.

V. The action of the 12 per mille solution of anhydrous magnesium sulphate is, as we have already said, different from that of a saturated calcium sulphate solution.

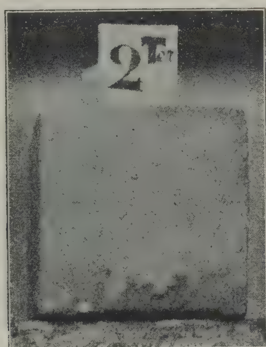
The silicious products containing at the best only 2 per cent of alumina and limes even keep much better in magnesium sulphate than in calcium sulphate, (see photographs 5 and 2), while the cements rich in alumina are decomposed with as much rapidity in sulphate of magnesium as in sulphate of calcium (compare photograph A 5).



Silicious cement after 6 years in the saturated solution of calcium sulphate.



Silicious cement containing less than 2 per cent of alumina after 6 years in the 12 per mille solutions of anhydrous magnesium sulphate.



Silicious cement containing less than 2 per cent of alumina after 6 years in the 12 per mille solution of anhydrous magnesium sulphate.

Cement containing 8 per cent of alumina after 21 months in the 12 per mille solution of anhydrous magnesium sulphate.

Silicious lime treated with lime stearate after 46 months in the 12 per mille solution of anhydrous magnesium sulphate.

The addition of calcium stearate and the augmentation of the index give, in the case of the magnesium sulphate solution better results than with the solution of calcium sulphate (see photographs 56 and 55).

The addition of artificial puzzolana and especially of dehydrated clay yields almost always favourable results, which are insufficient sometimes, however (see photographs I 078 and A 04).

The quantity of gauge water has more influence than with the solution of calcium sulphate.

As regards the date of the immersion, a rapid immersion is always unfavourable, with or without addition of puzzolana.

VI. We have already remarked that our experiments with artificial sea water are less advanced.

They confirm the superiority of silicious cements over aluminous cements (see photographs I 079 and A 9) and the favourable effect of the addition of dehydrated clay.

Contrary to what had been observed in the case of magnesium sulphate, the corrosion seems greater when the immersion takes place after the elapse of a month.

This phenomenon is perhaps due to the presence of sodium chloride which hastens the hardening of the immediately immersed mortars.

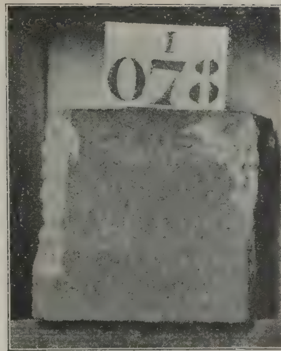
VII. The most curious result prominently brought out by these experiments is the very distinct difference in the actions of solutions of calcium sulphate and of magnesium sulphate. While the materials free of alumina which we have studied were rapidly decomposed in calcium sulphate, they resisted a long time and almost indefinitely the attacks of solution of magnesium sulphate; that would explain the reputation of limes and of silicious cements for use in sea water.

The action of puzzolanas is always more marked with solutions of calcium sulphate than with magnesium sulphate.

Yet when decomposition sets in with magnesium sulphate in mortars to which puzzolanas have been added, it happens sometimes that the decomposition is arrested, and that the fissures remain stationary.

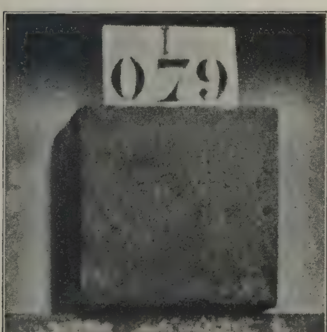
We may then, it would appear, actually assert that in practice silicious cements and even silicious limes (if we could employ them in the same composition as cements) should, in the actually

Silicious cement treated with calcium stearate after 46 months in the 12 per mille solution of anhydrous calcium sulphate.

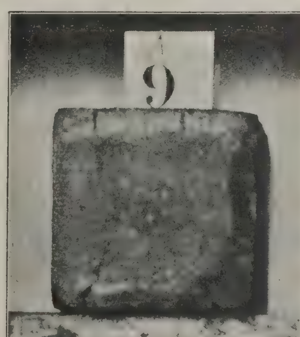


Silicious cement after 32 months in the 12 per mille solution of anhydrous magnesium sulphate.

Silicious cement mixed with clay after 34 months in the 12 per mille solution of anhydrous magnesium sulphate.



Silicious cement after 3 months in artificial sea water.



Cement containing 8 per cent of aliminia after 21 months in artificial sea water.

employed proportions, be almost indecomposable în solutions of magnesium sulphate[1]). A slight addition of dehydrated clay promises still further to improve their durability.

In the presenee of sulphate of calcium the use of dehydrated clay is the only means at present known of preventing decomposition. We point out that this addition of dehydrated clay cannot be made in the yard, but must be entrusted to conscientious manufacturers who have long been thoroughly familiar with all the manipulations of this fabrication.

For four years the Société J. et A. Pavin de Lafarge has supplied an indecomposable cement based upon a mixing of dehydrated clay and of the silicious cements of the firm.

This ciment has been employed in gypsiferous territories by the Compagnie des Chemins de Fer Paris—Lyon—Méditerranée and by the Cie. des Chemins de Fer de Ceinture de Paris. This Society thus deserves credit for having made novel and incontestable progress in the manufacture of hydraulic materials.

We believe moreover that it will be equally possible to obtain materials which will absolutely resist the action of calcium sulphate and probably of magnesium sulphate by manufacturing fused cements. We have already succeeded in preparing quite a scale of such cements which we have patented; the experiments, so far made with them, are very encouraging, but of too recent date to say anything further.

We shall be very glad if these experiments, made in our modest sphere, have provided a useful contribution to the solution of a difficult problem. They will already have rendered useful service if they merely serve to call forth further investigations of this delicate question.

We wish, in any case, to express our thanks to Mr. Henry Le Chatelier for the kind advice he has given us as to the manner in which to conduct our research.

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[1]) Brussels Congress, Report by Meyer, in general and in particular under experiment 73 bis June 1858.

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30 **Norwegiseher Zentralverein für Handwerk u. Industrie,** Kristiania.
31 **Nylands mech. Werstätte,** Aktiengesellschaft, Kristiania.
32 **Saxegaard, M.,** Abteilungs-Ingenieur der Staatsbahnen. Hönefos.
33 **Schmelck, L.,** Stadtchemiker, Kristiania.
34 **Simonsen, E.,** Chemiker, Kristiania, Handelsgymnasium.
35 **Skabo,** Wagenbauwerkstätte, Sköien pr. Kristiania.
36 **Telegraphenwesen, Kgl. norweg.,** Kristiania.
37 **Thams & Cie., M.,** Trondhjem.
38 **Trondhjems Ingenieurwesen,** Trondhjem.
39 **Trondhjems technische Lehranstalt,** Trondhjem.
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42 **Vulkan,** mech. Werkstätte, Kristiania.
43 **Wasserbaudirektorat, Kgl. norweg.,** Kristiania.
44 **Wegebau-Direktorat Kgl. norweg.,** Kristiania.
45 **Wetlesen, Thorvald,** Ingenieur, Kristiania.
46 **Widerberg,** Ing.-Capitain, Kristiania, Akershus.

Portugal.

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15 **Salles Ramos da Costa (Francisco de)**, Lieutenant Colonel d'Artillerie, Directeur de la Fonderie de Canons. Travessa do Convento de Jesus 15, Lisbonne.

Roumanie — Rumänien — Roumania.

1 **Balaban, Emile,** Inspecteur général, strada Romana No. 118, Bucarest.
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12 **Pfeiffer, Gr , Dr.**, professeur et chef des laboratoires d'essai de l'Ecole des ponts et chaussées.
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14 **Romnicianu M.,** Inspecteur général. Sous-Directeur général des chemins de fer de l'Etat Roumain, Bucarest.
15 **Saligny, A.,** Inspecteur général, Directeur général des Services hydrauliques strada Occident No. 15, Bucarest.
16 **Şantierul Naval,** Turnu-Severin (Roumanie).
17 **Scoala de Poduri şi Sosele**, Calea Griviţei No. 132, Bucarest.
18 **Serviciul de Poduri şi Sosele al M. L. P.**, strada Michai Vodâ No. 9, Bucarest.
19 **Wolff E.**, Ingénieur constructeur d'usines de métallurgie, strada Sf. Dumitru 3, Bucarest.
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Russie — Rußland — Russia.

1 **Abramoff, N.,** ingénieur des voies de comm., directeur du laboratoire mécanique de l'Institut Polytechnique de Don, Nowotscherkassk.

2 **Académie du génie militaire de l'Empereur Nicolas I**, St.-Pétersbourg.

3 **Adadouroff, N.,** ingénieur, président du conseil du génie au ministère des voies de communication, St.-Pétersbourg, Nadejdinskaya, 31.

4 **Adametzky, V.,** Ingenieur der Eisengießerei Huta-Bankow, Dombrowa.

Administration des chemins de fer de l'Empire, St.-Pétersbourg.

Représentant:

5 **Bogouslavsky, N.,** ingénieur.

Administration du chemin de fer de l'Asie Centrale, Askhabad.

Représentants:

6 **Tscharkowsky, A.,** ingénieur du service de la voie.

7 **Tolotschko, Z.,** ingénieur du service de la traction.

8 **Administration du chemin de fer de Baskountschak,** st. Akhtouba.

Administration du chemin de fer de Cathérine, Ekathérinoslaw.

Représentants.

9 **Andojsky, D.,** ingénieur en chef de la section technique.

10 **Andrééff, A.,** ingénieur adjoint du service de la voie.

11 **Münzer, A.,** directeur du laboratoire.

Administration du chemin de fer Libau-Romny, Minsk.

Représentants:

12 **Ivanoff, J.,** ingénieur en chef de la section technique du service de la voie.

13 **Efimoff, P.,** ingénieur-technologue de la section technique du service de la traction.

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Représentants:

14 **Viktoroff, G.,** ingénieur-adjoint du service de la voie.

15 **Pachkowsky, M.,** ingénieur-technologue, ingénieur-adjoint du service de la traction.

16 **Administration des chemins de fer Moscou Koursk et de Nijny Novgorod,** Moscou.

17 **Administration du chemin de fer de l'Empereur Nicolas I,** St.-Pétersbourg.

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Représentants:

18 **Bajanoff, L.,** ingénieur-technologue, adjoint du service de la traction.

19 **Nekludoff,** ingénieur du service de la voie.

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Représentants:

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21 **Stojaroff, J.,** ingénieur technologue, ingénieur du service de la traction.

22 **Tschknavoriantze,** ingénieur chimiste, directeur du Laboratoire.

23 **Administration du chemin de fer de Perm.**

Administration des chemins de fer de Poléssié, Vilna.

Représentant:

24 **Kouzmenko, W.,** ingénieur en chef du service de la voie.

Administration du chemin de fer Riga-Orel, Riga.

Représentant:

25 **Boffemel, A.,** ingénieur des voies de comm.

26 **Administration du chemin de fer Samara-Zlatooust,** Samara.
Administration du ehemin de fer de la Sibérie, Tomsk.

Représentants:

27 **Ingénieur en chef du service de la traction.**

28 **Ingénieur en chef du service de la voie.**

Administration des chemins de fer du Sud, Kharkow.

Représentants:

29 **Schmidt, W.,** ingénieur en chef du service de la voie.

30 **Skoupewsky, B.,** ingénieur en chef du service de la traction.

Administration des chemins de fer du Sud-Ouest, Kiew.

31 **Pogrébinsky, M.,** ingénieur en chef du service de matériel,

32 **Kich, A.,** ingén. du service de la voie.

33 **Yanouchewsky, P.,** ingénieur du service de la traction.

34 **Administration du chemin de fer Syzran-Wiazma,** Kalouga.

35 **Administration du chemin de fer de Taschkent,** Taschkent.

36 **Administration des chemins de fer de Transbaïkal,** Irkoutsk.

37 **Administration des chemins de fer Transcaucasiens,** Tiflis,
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Représentant:

38 **Belelubsky, A.,** ingénieur en chef du service de la voie.

39 **Administ ation des Voies navigables du bassin d'Amour sibérie de l'Est,** Blagowestschensk.
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Représentant:

40 **Krouglikoff N.,** ingénieur des voies de comm.; St. Pétersbourg, Italianskaya 33.

41 **Administration du chemin de fer Moscou-Vindau-Rybinsk;** Saint Pétersbourg, Demidow 1.
Administration de chemin de fer Kowel-Vladimir-Volyne; Kowel.

Représentants:

42 **Tschetscheleff C.,** Ingénieur en chef du service de la voie, colonel du corps du génie militaire; Kowel.

43 **Fetting V.;** Ingénieur en chef du service de la Traction, colonel du Corps du génie militaire; Kowel.

44 **Administration des ingénieurs du Corps du génie militaire de Tiflis;** Tiflis, Ingenernaïa.
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Représentants:

45 **Verkhowsky A.,** ingénieur en chef du service de la Voie;

46 **Vinogradoff G.,** ingénieur en chef des Ateliers de Dwinsk.

47 **Akoronko, T.,** ingénieur des voies de communication, St.-Pétersbourg, Administration du chemin de fer de l'Empereur Nicolas I.

48 **Akscharoumoff. N.,** Ingenieur-Chemiker, Baku, Zementfabrik.

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Vertreter:

51 **Johannsen, R.,** Ingenieur. Direktor der Gesellschaft, Moskau, Mjasnitzkaja, Haus Ermakoff.

52 **Alphéraky, M.,** Conseiller d'état, Taganrog.

53 **Amberger, G.,** Ingenieur der Eisengießerei Huta-Bankowa, Dombrowa.

54 **Andrieux, J.,** directeur de la Cie Franco-Russe des ciments Portland, Guélendjik près Novorossisk.

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59 **Bacmeteff, J.,** ingénieur, conducteur des travaux du port commercial de Libau, Libau.

60 **Baldine, A.,** ingénieur, Zaporojié-Kamenskoë.

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65 **Belelubsky, N., Dr.-ingén.,** professeur émérite, vice-président de l'Association internationale pour l'essai des matériaux, membre du conseil du génie au ministère des voies de comm., directeur du laboratoire méc. à l'institut Impérial des ing. des voies de comm., St.-Pétersbourg, Bronnitzkaya, 14 a.

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71 **Bobrowsky, S.,** lieutenant-colonel du corps du génie militaire, St.-Pétersbourg, perspective de Souvoroff, 15.

72 **Bobylew, D.,** Professor der Universität, St. Petersburg, Universität.

73 **Bogdanoff, N.,** ingénieur civil adjoint au laboratoire mécanique de l'institut impérial des ing. des voies de comm., St.-Petersbourg, Wass. Ostr. 4me ligne 47, log. 5.

74 **Bogouslawky, N.,** ingénieur des voies de comm., conseiller d'Etat actuel, St.-Pétersbourg, Razjezjaya, 11.

75 **Botscharoff, P.,** Miassnitzky proesd 2, Moscou.

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78 **Brandt, A.,** directeur de l'institut des ingénieurs des voies de communication, professeur, Saint-Pétersbourg, Zabalkansky, 9.

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82 **Bureau des chimistes Ouraliens,** Ekaterimbourg, Laboratoire d'Etat.

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Représentants:

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84 **Suzor, P.,** comte, vice-président.

85 **Bogdanoff, N.,** ingénieur, secrétaire.

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Représentant:

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87 **Chechmintzeff, L.,** ingénieur-mécanicien, Diatkowo, gouvernement Orel.

88 **Chtchoukine,** professeur à l'institut technologique de St.-Pétersbourg, membre du conseil du génie au ministère des voies de comm., St.-Pétersbourg, Zabalkansky, 18.

89 **Cieschkowsky,** Ingenieur der Eisengießerei Huta-Bankowa, Dombrowa,

90 **Ciszewsky, J.,** ingénieur des voies de comm., St.-Pétersbourg. Moika, 40, Adm. du ch. de fer Riazan-Oural.

Comité géologique, St.-Pétersbourg, 4me ligne, Wass. Ostr. 15.

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Comptoir Demidoff, (héritiers du prince Demidoff San Donato), St.-Pétersbourg, Wass. Ostr., 4me ligne 61.

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94 **Czarnomsky, W.**, ingénieur des voies de comm., St.-Pétersbourg, Kirotschnaya, 32—34.

95 **Danilewsky, N. de.**, ing. technologue, ancien directeur général des usines Poutilow, St.-Pétersbourg. Fourstadtskaya, 36.

96 **Depp S.**, colonel du corps du génie militaire, St.-Pétersbourg, Morskaya, 17.

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Firma ,,Gustav List".

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Représentant:

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107 **Gesellschaft für Zementfabrikation am Schwarzen Meere,** Noworossisk.

108 **Girard de Soucanton E., Baron,** Besitzer der Zementfabrik Port-Kounda, St. Wesenberg, Baltische Eisenbahn.

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110 **Goguel, Th.**, ingénieur, Biejetza, gouv. Orel.

111 **Graftio, H.**, ingénieur des voies de communication, St.-Pétersbourg, Kamennoostrowsky, 24

112 **Grooten Max.**, Ingenieur-Technolog, St.-Pétersbourg, Italianskaya, 11.

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115 **Guétmanoff, A.**, propiétaire des carrières Koutschuk-Saraị, Yalta (Crimée).

116 **Haller v. Ch.**, général-major du génie militaire, Batoume.

117 **Herberts, B.**, directeur général de la société métallurgique de Jurjevsk, St.-Pétersbourg, Kronwersky, 79.

118 **Hirschson, H.**, Direktor der Gesellschaft „Eisenbeton", St.-Pétersbourg, Sapernoï 23.

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122 **Jelislawsky, J.**, président de l'administration de la fabrique de ciment „Firley", Lublin.

123 **Jitkewitsch, N.**, colonel du corps du génie militaire, S.-Pétersbourg, canal de Cathérine, 64.

124 **Jodello, Fr.**, Ingenieur-Technolog, Kiew, Polytechnisches Institut.

125 **Joukowsky, S.**, ingénieur des mines, St.-Pétersbourg. Gorokhowaya, 62.

126 **Justus, L.**, ingénieur des voies de communication, Nicolaieff.

127 **Kalinnikoff, J.**, ingén.-méc., Moscou, Ecole Impériale technique, Laboratoire mécanique.

128 **Kamiensky, G.**, ingénieur, Varsovie.

129 **Kannegiesser, J.**, ingénieur des voies de communication, St.-Pétersbourg, Sapernoy. 10.

130 **Kareischa, S.,** professeur è l'institut impérial des ingénieurs des voies de communication, St.-Pétersbourg, Zagorodny, 70.
131 **Karelskich, K.,** Ingenieur, Mechaniker, Moskau.
132 **Khitrowo, N.,** ingénieur-technologue, St.-Petersbourg, Schpalernaïa, 56.
133 **Khozro-Gadjar,** prince ingénieur des voies de communication, inspecteur, Sossnowice.
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140 **Kouharsky V.,** colonel du Corps du génie militaire; Kronstadt, Yakorny Dwor.
141 **Kouperstein, B.,** ingénieur, Brest-Litowsk, Gouv. Grodno.
142 **Kriloff, A.,** inspecteur général des contructions navales. St.-Pétersbourg, Zwerinskaya, 6—8.
143 **Kriloff J.,** colonel du Corps du génie militaire, Toula.
144 **Kroupsky, A.,** professeur de l'Institut technologique à St.-Pétersbourg, St.-Pétersbourg. Bronnitzkaya 22.

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Représentant:

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Représentant:

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Représentants:

147 **Belelubsky, N.,** professeur, directeur, du laboratoire.
148 **Bogdanoff, N.,** ingénieur civil.
149 **Nowgorodsky, D.,** ingénieur.

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150 **Moscicky,** ingénieur, Varsovie, Dobra 27.

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Représentant:

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153 **Laboratoire Mécanique à l'Institut Polytechnique de Kiew,** Kiew.

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Représentant:

154 **Lachtine, N.,** directeur du Laboratoire.

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155 **Proscouriakoff,** prof., directeur du laboratoire.
156 **Lamine, N.,** prof. adjoint à l'institut des ing. des vois de comm., St.-Pétersbourg, Fontanka, 128.
157 **Landau, J.,** ingénieur de la société de Batignolles, St.-Pétersbourg. Fontanka 4.
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163 **Lieven, V.**, chimiste, directeur de la société de l'usine de ciment Noworossisk, Riga.
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77 **Vassaux, Ernest,** Directeur des Usines du Furcil à Noiraigue.
78 **Verein schweizerischer Zement-, Kalk- und Gipsfabrikanten.**
79 **Verein schweizerischer Maschinen-Industrieller,** Zürich.
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INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

II4

INVESTIGATIONS ON THE BRINELL METHOD OF DETERMINING HARDNESS.

By **Harold Moore** B. Sc., Woolwich Arsenal, England.

The application of the ball-hardness test in the Research Department of the Royal Arsenal, Woolwich, to test pieces of widely varying size and shape, and at many points in the same test piece, has rendered necessary the determination with some care of the limiting conditions of the test. The work described below was accordingly undertaken to determine 1. the minimum thickness of test piece, 2. the minimum distance of impression from edge of test piece, which may safely be employed, 3. the approximate error introduced by exceeding the limiting conditions determined in 1 and 2.

The numerous tests, made on several different materials, with load and diameter of ball both varying through a considerable range, have afforded a means of checking the conclusions of other workers as to the effect of variation in load and diameter of ball upon the hardness number. The results obtained have led to the suggestion of a new method of calculating the hardness number.

All the tests were made in a 4000 kg multiple lever machine. The load was slowly applied and maintained for 10 seconds at the maximum reached. The impressions were measured by means of a measuring microscope reading to 0·001 millimetre; the diameter of impression given is in each case the mean of two measurements, of diameters at right angles to each other. The test plates were planed smooth on both faces; the face in which the impressions were made was polished. During the loading the

test plate rested on a polished plate of hardened steel. The diameters of the balls used in the tests were 5, 10 and 15 millimetres. A 4 mm-ball was used in testing the uniformity of hardness of some of the materials.

1. Minimum thickness of test piece.

The method employed was to make hardness measurements with successively increasing loads, upon two plates of the same metal, one much thicker than the other, until a difference, due to the insufficient thickness of the thin plate, was detected. By using balls of different sizes with the same thickness of plates, the author hoped to determine the limiting size of impression at different angles of impression. As in most investigations of methods of hardness measurement, the chief difficulty met with was the variation in the hardness of the same piece of metal from point to point. It must indeed be placed to the credit of the Brinell method that it has revealed a hitherto unsuspected variation of hardness in masses of metal which might be expected to be of uniform hardness. It was considered preferable to make each loading at an undisturbed point of the surface; the tests of series A were carried out in this manner.

In order to eliminate as far as possible the effect of variation of hardness, series B tests were made by successive loadings of the test piece at the same point, with increasing load. Another set of materials was used for this series of tests.

Series A tests were carried out on discs cut from round bar 80 mm diameter, of rolled brass annealed at 570^0—580^0 C., and of mild steel, and on plates cut from a bar 50 mm square of nickel chromium steel, specially heat treated to give uniform hardness.

The uniformity in hardness of the metals used in series A was tested by making 3 to 7 impressions in each of two or more thick plates of each metal, with the same ball and load. In the mild steel the greatest difference found was 2 per cent of the diameter of impression; in the harder steel and the brass it did not exceed 1 per cent. Some of the results given by series A tests are given in tables I and II. The method by which the hardness numbers are calculated, will be stated, together with the reasons for adopting it, in section 3 of this paper. All measurements are given in millimetres.

Table I. Series A tests. Mild Steel.

Load kg	5 mm ball			10 mm ball			15 mm ball		
	Thickness of plate = 15·05		Thickness of plate = 3·20	Thickness of plate = 15·03		Thickness of plate = 3·20	Thickness of plate = 15·06		Thickness of plate = 3·15
	Diameter of impression	Hardness number	Diameter of impression	Diameter of impression	Hardness number	Diameter of impression	Diameter of impression	Hardness number	Diameter of impression
400	2·076	125·4	2·057	—	—	—	—	—	—
500	2·272	127·3	2·251	2·498	127·4	2·493	2·605	130·9	2·641
600	2·421	131·7	2·434	—	—	—	—	—	—
700	2·627	127·2	2·618	—	—	—	—	—	—
800	2·775	128·1	2·773	3·040	128·9	3·048	—	—	—
900	2·928	127·2	2·928	—	—	—	—	—	—
1000	3·050	128·6	3·076	3·382	125·9	3·377	3·557	127·7	3·530
1100	3·163	129·9	3·203	—	—	—	—	—	—
1200	3·287	129·3	3·316	—	—	—	—	—	—
1300	3·435	126·9	3·436	—	—	—	—	—	—
1500	3·629	128·6	3·628	4·028	126·0	4·025	4·212	129·7	4·211
1700	3·826	129·0	3·810	—	—	—	—	—	—
2000	4·030	133·8	4·070	4·515	128·8	4·567	4·809	126·8	4·808
2500	—	—	—	5·013	126·5	4·975	—	—	—
3000	—	—	—	5·402	127·4	5·432	5·745	126·0	5·690
3500	—	—	—	5·795	126·5	5·880	—	—	—
4000	—	—	—	6·228	122·5	6·118	6·466	128·0	6·452

Table II. Series A tests. Annealed brass.

Load kg	5 mm ball			10 mm ball			15 mm ball		
	Thickness of plate = 14·85		Thickness of plate = 3·37	Thickness of plate = 14·85		Thickness of plate = 3·34	Thickness of plate = 14·87		Thickness of plate = 3·28
	Diameter of impression	Hardness number	Diameter of impression	Diameter of impression	Hardness number	Diameter of impression	Diameter of impression	Hardness number	Diameter of impression
300	2·019	104·2	2·014	2·286	107·1	2·285	—	—	—
500	2·503	101·6	2·502	2·870	101·1	2·871	3·026	109·4	3·047
700	2·830	104·7	2·807	3·270	102·2	3·300	3·491	107·2	3·523
1000	3·246	106·2	3·270	3·777	101·8	3·813	4·060	105·0	4·090
1500	3·847	104·1	3·868	4·437	102·1	4·474	4·780	104·7	4·841
2000	4·270	106·9	4·322	4·962	102·9	5·030	5·380	103·9	5·311
3000	—	—	—	5·854	102·1	5·906	6·341	103·3	6·318
4000	—	—	—	—	—	—	7·132	102.7	7·139

Series B tests were made on other samples of mild steel, brass and copper. Owing to limitation of space it is not possible to include the detailed results of the tests.

In no case does the difference of diameter between corresponding impressions on thick and on thin pieces exceed 2%, when the ratio of depth of impression to thickness of test piece is not greater than $1/3$. A closer analysis of the figures, taking into consideration the variation in hardness of the metals employed, leads to the conclusion that within the ratio $1/3$ the effect of thickness of test piece is well within $1{\cdot}5\%$ on diameter, corresponding to about 3% on hardness number. Errors of 3% are however much too large for accurate work. Another consideration renders the employment of very thin test plates inadvisable. When the depth of impression is a large fraction of the thickness, the test plate is considerably deformed by the test. This is especially so when the area of the test plate is small. The thin discs of series B tests were distorted into a shallow funnel shape, the circumference of the disc rising away from the supporting hard steel plate during the test.

When the depth of impression exceeds $1/16$ the thickness of test piece, a polished area is produced on the reverse side of the test plate, opposite the impression, caused by the pressing of the metal under the ball into close contact with the polished supporting plate. When the depth of impression exceeds $1/7$ the thickness of test piece, the metal surrounding the impression is forced out of contact with the supporting plate, the reverse side of the test plate is no longer plane, a projection existing below the impression. These ratios are approximate only and must not be taken to apply to angles of impression much smaller than those generally employed.

Because of the variation in hardness of the metals employed, it is difficult to state the limiting thickness above which variation in thickness has no effect whatever upon the test. Some attempt may however be made to deduce this limit by 1. rejecting the comparative tests not giving close agreement with small impressions, 2. not including impressions at very small angles of impression. The edge in these being difficult to define exactly, measurements of diameter cannot be relied upon. A disturbing factor which probably accounts for nearly all the differences observed between

the tests on thick and on thin pieces is, that contact between test piece and supporting plate was not absolutely perfect. To obtain perfect contact, both the surfaces in contact must be perfectly plane and polished. The lower faces of the test pieces were machined smooth, but not polished.

Taking all these points into consideration, the writer is of opinion, that if perfect contact exists between test plate and supporting plate (hard enough not to suffer any permanent deformation by the test), the thickness has no influence whatever upon the test when the depth of impression does not exceed $^1/_7$ the thickness of the test plate, and probably has no influence even when the depth is a much larger fraction of the thickness.

2. Minimum distance of impression from edge of test piece.

This was determined by ascertaining the minimum diameter permissible in a test cylinder when the impression was made at the centre of one end and was thus equidistant from any point of the edge. The first method tried was to impress cylinders of several different metals with increasing loads till an expansion of the cylinder was detected. This method was rejected 1. because a slight expansion of the cylinder was observed with relatively small impressions, and 2. because no indication was afforded of the amount of error introduced by cxceeding the limiting conditions. Three other methods were employed: a) to impress a series of cylinders of the same metal, of varying diameters, with the same ball and load, and to note the smallest diameter of cylinder giving the correct diameter of impression; b) to impress two cylinders of the same metal of different diameter, with successively increasing loads, till a difference in diameter of impression was noted; c) to carry out the same test as b), but using a fresh pair of cylinders of large and small diameters for each loading. In all cases the increase in diameter of cylinder was observed.

The limitation of length of paper necessarily imposed by the International Testing Association compels the omission of the detailed results of most of the tests made by the above methods. Only the figures obtained by method a) are given in table III. This appears to be the most satisfactory method, but demands the preparation of numerous test pieces. On each material the test was made with two widely differing angles of impression. The cylinders were all 10 mm high.

It will be seen that the impression becomes too large when the ratio of diameter of piece to diameter of impression is less than 4·5. The ratio is about the same for the considerably different angles of impression employed—about 22^0 and 44^0. This limiting ratio is fully confirmed by the other series of tests, the results of which are not given here, on other grades of mild steel, brass, and a harder nickel chromium steel.

A safe rule to adopt is that the centre of a Brinell impression should not be less than 2·5 times its diameter from the edge of the test piece.

3. Effect of variation in load and in ball diameter.

In the following section the symbols employed are H = hardness number, P = load in kilograms, D = diameter of ball, d = diameter of impression, α = angle of impression.

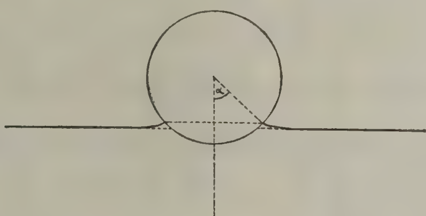

Fig. 1.

It has long been known that mean pressure per unit area in the ball test usually increases with increase in angle of impression. Various methods of calculating the hardness number have been proposed, to give the same figure whatever the size of ball and load employed. Le Chatelier (Revue de Métallurgie III, 1906, page 689) gives the following formula as established by Benedicks:

$$H = H_{DP} \sqrt[5]{\frac{D}{10}} \cdot \frac{20000}{17000 + P}$$

Applied to the Brinell hardness number

$$\left(\frac{\text{load}}{\text{area of spherical surface of impression}}\right)$$

given by any load and any ball diameter, this formula is supposed to give the hardness number which would be obtained with a 10 mm ball and 3000 kg. The formula has been applied to

Table III.

Mild Steel						Brass					
5 mm ball 1400 kg			10 mm ball 1600 kg			5 mm ball 1400 kg			10 mm ball 1300 kg		
Diameter of cylinder	Increase in diameter of cylinder	Diameter of impression	Diameter of cylinder	Increase in diameter of cylinder	Diameter of impression	Diameter of cylinder	Increase in diameter of cylinder	Diameter of impression	Diameter of cylinder	Increase in diameter of cylinder	Diameter of impression
24·3	0·005	3·475	—	—	—	24·3	0·005	3·484	24·3	0·002	3·890
24·1	0·010	3·463	24·3	0·005	4·038	24·2	0·012	3·495	24·2	0·012	3·881
22·2	0·010	3·468	22·2	0·007	4·038	22·2	0·015	3·473	22·2	0·005	3·900
20·1	0·005	3·462	20·1	0·010	4·042	20·2	0·012	3·510	20·2	0·007	3·901
18·1	0·005	3·472	18·1	0 017	4·057	18·3	0·027	3·507	18·3	0·015	3·902
16·1	0·010	3·484	16·2	0·025	4·156	16·3	0·015	3·521	16·3	0·020	3·920
14·2	0·025	3·508	14·2	0·035	4·165	14·2	0·056	3·553	14·2	0·032	3·946
12·2	0·045	3·545	12·2	0·052	4·297	12·2	0·045	3·580	12·2	0·040	3·993
10·2	0·070	3·606	10·2	0·087	4·430	10·2	0·065	3·611	10·2	0·070	4·092

measurements given in tables I and II and to many others, but does not by any means give a constant hardness number for a given metal. The formula has accordingly been rejected. The true relation between load and diameter of impression has been ascertained by Meyer, who has published his results in an important paper (Zeitschrift des Vereines deutscher Ingenieure, LII., 1908, p. 645).

The relation is expressed by the formula $P = ad^n$ in which n is a constant for a given metal and a is a constant for a given metal and a given ball diameter. Meyer has also shown that mean pressure per unit area $\frac{4P}{\pi d^2}$ is constant for a given angle of impression, whatever the diameter of ball. This was demonstrated some years ago by the writer, but not published; it has been more fully confirmed by numerous recent tests made by the writer. It is accordingly possible if the coefficient n is known, to calculate the mean pressure per unit area for any given angle of impression, from the diameter of impression given by any load and any ball diameter. As $\frac{4P}{\pi d^2}$ depends only on angle of impression and is not influenced by ball diameter, it only remains to select a definite angle of impression at which mean pressure per unit area shall be taken to represent the hardness, to obtain a hardness number which is constant for the given metal. Meyer contends that hardness cannot be represented by a single number and is fully represented only by two coefficients. However true this may be theoretically, it is of great practical importance to be able to employ a single constant as the hardness number of a substance, though this necessitates the arbitrary selection of a definite form of distortion.

It is suggested that 30^0 be chosen as the standard angle of impression, at this angle the diameter of impression = $^1/_2$ diameter of ball. The hardness number therefore becomes the mean pressure per unit area when the diameter of impression is one half the diameter of ball. The selection of a definite angle of impression rather than a given load and ball diameter offers many advantages. It is of perfectly general application, to substances of any hardness, and the definition of the hardness of a substance as the mean pressure per unit area required to produce distortion of a definite form appears to be reasonable and theoretically sound. It is not

at all necessary actually to make the diameter of impression one half the ball diameter. It is convenient in practice to employ a known load and measure the diameter of impression obtained. The hardness number is then obtained, from the measurement given by any load and any ball diameter, by applying the formula

$$\text{(a):} \qquad H = \frac{16 \ P \ D^{n-2}}{\pi \ (2 \ d)^n}$$

The hardness number calculated by the Brinell method, for the same angle of impression is $\frac{H}{1{\cdot}0718}$

The hardness numbers given in tables I—II are obtained by applying the formula (a).

In the great majority of practical hardness tests n may be assumed to be known with quite sufficient accuracy. Again if the test is made with an angle of impression not differing greatly from 30^0, the error introduced into the hardness number by a comparatively large error in the value of n is small. The coefficient n is readily determined by making two impressions with the same ball and different loads, and applying the formula

$$n = \frac{\log P_1 - \log P}{\log d_1 - \log d}$$

The significance of the coefficient n merits some attention. Undoubtedly the increase in mean pressure per unit area with increase of angle of impression is due to the hardening effect of cold work. When $n = 2$, $\frac{4 \ P}{\pi \ d^2}$ is unaffected by increase in angle of impression. n is generally between 2 and 2·5, the greater the value of n the more does $\frac{4 \ P}{\pi \ d^2}$ increase with increasing angle of impression: n therefore appears to represent the capacity of the metal to harden by cold work. More correctly, $n - 2$ represents capacity for hardening by cold work. Some tests, the detailed results of which are not here given, fully support this view, which would require that n should have a higher value in a metal in the soft condition than when cold-worked to the maximum possible degree. Metal in this hardened state and accordingly incapable of being further hardened by cold-work should have $n = 2$. The work of Beilby has shown that it is extremely difficult if not

impossible, to retain a metal in the state of maximum hardness produced by cold work, this explains why in the writer's experiments so low a value as 2 was not obtained for n.

Two copper crushers were compressed to $^1/_3$ of their original thickness. One was annealed for 2 hours at 500^0 C. One piece of brass strip was tested in the hard-rolled state, another piece of the same strip annealed along with the copper crusher.

Values of n:

Copper hard worked . . .	2·01
„ annealed	2·39
Brass hard rolled	2·06
„ annealed	2·53

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

VIII 1

ESTABLISHMENT OF INTERNATIONAL SPECIFICATIONS FOR IRON AND STEEL.

Report by the chairman of Committee I, Dr. Ing. **A. Rieppel**, Nürnberg.

(Translated from the German by A. R. Liddell, Charlottenburg.)

Summary.

1. Introductory Remarks.

Committee I is charged with the task of seeking for "methods and means for the introduction of international specifications for testing and inspecting iron and steel of all kinds".

The composition of Committee I and the results of their labours hitherto may be seen from Report 1 d, presented to the Brussels Congress of 1906. According to the latter, the work progressed very slowly, because most countries were devoid, not only of uniform national specifications for iron and steel material, but also of corporate bodies (associations for the testing of materials) which could suitably take in hand the unification of the existing specifications. These preliminary requirements were in some measure fulfilled only in the three countries mainly concerned in the production of iron and steel, viz. Germany, England, and the United States of North America. It was accordingly determined at the Brussels Congress of 1906, that a sub-committee consisting of representatives of the three countries named be formed, which should endeavour to establish international specifications on the basis of German, English, and American standard conditions. The formation of the Committee was attended with difficulties, so that the appointments to it were not all made till the beginning of 1909.

2. Problem.

Committee 1 a shall, on the basis of specifications recognized by the national testing associations of Germany, England and the United States of North America (see under 4), endeavour to establish uniform international specifications for the delivery of materials to countries that do not themselves produce iron in any considerable quantities.

3. Members.

Chairman: v. Rieppel, Chairman of Committee I.

Representatives of Germany:

Professor R. Stribeck in Firma Friedr. Krupp, Essen-Ruhr.

Direktor Vehling, Aachener Hüttenverein, Rote Erde, bei Aachen. (Proposed by the Verein deutscher Eisenhüttenleute.)

Representatives of England:

F. W. Harbord, 16, Victoria Str., London, S. W.

F. E. Robertson, M. Inst. C. E., London, S. W. 8, Great George Street. (Proposed by the English Members of the International Association for Testing Materials.)

Representatives of the United States of North America:

W. R. Webster, Civil Engineer, 411—413 Walnut Street, Philadelphia, Penna.

W. Wood, Cost Iron Pipe Manufacturer, R. D. Wood Comp., 400 Chestnut Str. Philadelphia, Penna. (Proposed by the American Society for Testing Materials.)

4. Bases.

a) German specifications recognized by the Deutscher Verband für die Materialprüfungen der Technik:

1. Entwürfe für einheitliche Vorschriften für Oberbaueisen,
2. „ „ „ „ „ Bauwerkeisen,
3. „ „ „ „ „ Schiffbaueisen,
4. „ „ „ „ „ Walzrohre,
5. „ „ „ „ „ Draht,
6. „ „ „ „ „ Gußeisen (ausgenommen Gußröhren, über welche der deutsche Verband 1908 noch nicht endgültig beschlossen hat).

b) English specifications, published by the Engineering Standards Committee, London:

1. Specification and sections for tramway rails and fishplates,
2. British standard specification for tubular tramway poles,
3. British standard specification and sections for bull-headed railway rails,
4. British standard specification and sections for flat-bottomed railway rails,
5. British standard specification for structural steel for shipbuilding.
6. British standard specification for structural steel for marine boilers.
7. British standard specification for telegraph material,
8. British standard specification for structural steel for bridges and general building construction.

c) American specifications adopted by the American Society for Testing Materials:

1. Standard specifications for cast iron car wheels,
2. „ „ „ gray iron castings,
3. „ „ „ structural steel for bridges and ships,
4. „ „ „ steel axles,
5. „ „ „ „ forgings,
6. „ „ „ „ castings,
7. „ „ „ foundry pig-iron,
8. „ „ „ cast-iron pipe and special castings,
9. „ „ „ locomotive cylinders,
10. „ „ „ malleable castings,
11. „ „ „ structural steel for buildings.
12. „ „ „ open hearth boiler plate & rivet steel,
13. „ „ „ steel rails,
14. „ „ „ steel splice bars,
15. „ „ „ steel tires,
16. „ „ „ wrought iron.

INTERNATIONAL ASSOCIATION FOR ◻
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◻ V^TH CONGRESS, COPENHAGEN 1909. ◻

VIII 3

ON STANDARD SPECIFICATIONS FOR THE PURCHASE OF COPPER.

Report of the Copper Committee, by Prof. **Léon Guillet**, Paris.

Translated by G. Lemmy.

The Committee appointed by the Council for the study of suitable conditions to form the basis of specifications for the inspection of copper consists of the following membres (Mr. L. R. v. Stockert, Vienna, and Mr. Gerwer, Zurich, having resigned:

President: Mr. *Léon Guillet,* Chief Engineer of the Chemical Dept. with Messrs. de Dion-Bouton; Prof. au Conservatoire des Arts et Métiers, 17, Avenue Carnot, Paris XVII.

Members: Mr. *H. C. Heckmann,* Duisburg-Hochfeld.

Mr. *H. G. Selve,* Geh. Kommerzienrat, Altena i. W.

Dr. *R. T. Glazebrook,* Director National Physical Laboratory, Teddington.

Mr. *F. Tomlinson,* The Broughton Copper Co. Ld, N. Manchester.

Mr. *G. Guillemin,* Consulting Engineer, Paris V.

Mr. *P. Breuil,* Chief of Metal Testing Section, Laboratoire des Arts et Métiers, Paris.

Mr. *P. Olgouine,* Engineer, Mech. Laboratory of Imperial School oı Engineers, Moscow.

Mr. *E. Wehrenfennig,* Central Inspector of the Austrian North Western Railway, Vienna.

Mr. *P. Zugmayer,* Engineer, Copper Manufacturer, Waldegg (Niederösterreich).

Mr. *C. E. Skinner,* Electrical Engineer, Westinghouse Electric Manufacturing Co., East Pittsburgh, Pa. (U. S. A.).

Mr. *H. E. Diller,* The Hawthorne Engineering Laboratory, Western Elec. Co., Chicago (U. S. A.).

Owing to the very short time which has elapsed between the appointment of this Committee and the date (Jan. 1909) on which the present report was handed in, it is quite clear that there was no possibility of arriving at a decision in the matter of standard specifications.

The sole object of this report, therefore, is to indicate in what position the work carried out by the Committee now stands. The work in question has dealt with the preparation of a comparative abstract of the different specifications concerning copper; the abstract has been written by the President aided by the various Members, (Mr. Breuil more especially), who kindly gave their help for carrying the work to a satisfactory issue.

Each member was invited to put forward his criticism in regard to existing specifications, together with his observations on copper testing. Various queries were put before the members as stated below, and in order that the replies be correctly interpreted, the President has deemed it advisable to reproduce them as textually as the scope of the paper will permit.

Replies obtained.

Queries 1 and 2.

Would it be advisable in your opinion to divide the Committee into two Sub-Committees the object of which would be to consider the use of copper for general engineering purposes, and for electrical work?

If so, to which Sub-Committee would you wish to belong?

Messrs. Glazebrook and Tomlinson replied in the affirmative, stating that they were interested in both sections and adding that the work of the Electrical Section would probably be an easy one.

Mr. Skinner said that the division did not appear to him a desirable one, the mechanical and electrical properties having to be gone into simultaneously.

Mr. Diller asked that a division should be effected and said he would like to form part of the Sub-Committee entrusted with the study of the physical properties of copper.

Messrs. Zugmayer and Wehrenfennig advocated the division and asked to form part of the Sub-Committee entrusted with copper for general engineering purposes.

Messrs. Selve and Heckmann did not think a division necessary.

Messrs. Breuil, Guillemin and Guillet did not think it necessary either.

In view of these replies, seeing also that no member had expressed a wish to form part of the Sub-Committee for the use of copper in electrical work, the President did not deem it necessary to divide the Committee.

Queries 3 and 4.

Are there in your Country specifications relating to the various uses of copper for general engineering purposes or for electrical work?

Would it be possible to you to send us a copy of, or an abstract from, such specifications?

Messrs. Glazebrook and Tomlinson called attention to the specifications of the Engineering Standards Committee of which an abstract is given later on.

Mr. Diller knew of no good specification relating to copper which dealt with any condition apart from electrical resistance and occasionally elongation and breaking stress. The elastic limit, he added, caused many difficulties when it formed part of the specifications.

Messrs. Zugmayer and Wehrenfennig referred to the specifications of the Austrian State Railways as being those generally worked to in Austria. An abstract of same is given further on.

Messrs. Selve and Heckmann gave similar information in regard to Germany.

Mr. Skinner could not find any specification dealing with the different uses of copper for general engineering and for electrical purposes.

Messrs. Breuil and Guillemin sent us various French specifications mentioned further on. Mr. Breuil has had the kindness to make an abstract of several of these.

Queries 5 and 6.

Do you know of difficulties having arisen in the working of these specifications and have you any modifications to propose?

Messrs. Glazebrook and Tomlinson stated that those of the Engineering Standards Committee were much appreciated by the Trade and that they gave satisfaction; no modification appeared necessary at the present time. (Meetings are held annually, in the course of which the question of modifications is considered.)

Mr. Zugmayer found the conditions, he called attention to, and which copper has to meet, good and of practical value as a whole; he however made the following objections:

a) Allowance in regard to thickness and weight:

The allowance up to 3% which is granted, appeared to be sufficient for all copper material, with the exception of wide plates for the manufacture of fire-boxes.

The largest rolls, 900 mm ($35^1/_2$ in.) and over, in diameter, used for rolling wide plates may curve in occasionally to a slight extent, say up to $^3/_4$ mm (0·029 in.) so that a wide plate may be $1^1/_2$ to 2 mm (0·059 to 0·078 in.) thicker in the centre than at the sides and it is at the sides that they are measured. For this, there is so far no remedy, and some of the plates are heavier than they should be theoretically. The Austrian Manufacturers endeavour, for wide plates, to obtain the application of the following conditions which are based upon practical results:

For plates up te 2300 mm (7 ft. $6^1/_2$ in.) wide, $3{\cdot}0\%$ allow. on weight.

For plates 2300 to 2600 mm (8 ft. $6^5/_6$ in.) wide, $3{\cdot}5\%$ allow. on weight.

For plates 2600 to 2800 mm (9 ft. $2^3/_{16}$ in.) wide, $4{\cdot}0\%$ allow. on weight.

For plates 2800 to 3000 mm (9 ft. $10^1/_8$ in.) wide, $4{\cdot}5\%$ allow. on weight.

For plates 3000 to 3100 mm (10 ft. 2 in.) wide, $5{\cdot}0\%$ allow. on weight.

For plates 3100 to 3200 mm (10 ft. 6 in.) wide, $6{\cdot}0\%$ allow. on weight.

b) For bars and plates there are tensile tests and bending tests, the two are now sufficient, and when one test does not succeed, it can be repeated, when, if it fails, the piece is rejected.

Mr. Zugmayer believed that the tensile test had several disadvantages. The tensile testing machine is a costly one and the various types of machines have not all the same practical value. When the machine has been in use some time, it gives varying results, and the repairing of a testing machine is a delicate matter. In practice therefore these machines give almost always divergent results. Besides, results differ if fracture is brought about rapidly or slowly. There is also the risk of an error in taking the measurements and it is no more possible to trace an error when once the test piece is broken, the initial conditions having dissappeared.

Further, added Mr. Zugmayer, a test piece whatever care be given to its preparation, has not throughout a perfectly uniform transversal section. Though the metal be of good quality, the test piece breaks at its weakest point, but this point cannot always be traced on measuring, and the size of a test piece can easily be made too small by probably $^1/_4$ mm (0·0098 in). For example a test piece which should be 16×20 mm ($0·63 \times 0·79$ in.) may really mesure at its weakest point $15·75 \times 19·75$ mm ($0·62 \times 0·78$) and its smallest transversal section, instead of having an area of 320 mm^2 (0·495 sq. in.) will only have 311 mm^2 (0·482 sq. in.). Under these conditions a breaking strain of 22·2 kg would be reduced to $22·2 \times {}^{311}/_{320} = 21·6$ kg and the plate from which it was taken, and for which 22 kg were required, would be rejected and wrongly so. Although the test piece may generally break in its centre it can also break near an end, either because the weakest point was at that end, or because the piece contracted at two places and had, perhaps by exception, a uniform thickness.

Fracture of a test piece near an end is not an exceptional occurrence. In such a case the calculation of the results is unfavourable to the test piece, for (as can be seen from specifications), the elongation only of the greatest half of the piece is compared with the total length; in this greatest half however the piece elongates less than at the point of fracture, and consequently the result is less good than if the calculation were based on the whole piece and on its total elongation.

c) Mr. Zugmayer added that the essential requisite in regard to tests was that these shoud have a practical value. It was necessary, in other words, that tests should fulfil, on a small scale, the conditions which the material is destined to meet when in servece. From this point of view, the opening out and the flanging of tubes, the stamping out of rivet heads, the threading of bars, the bending double of thin plates, appeared to him to be most excellent tests. In his opinion, however, the bending test was by far the most satisfactory. This should be required in every instance, and more importance should be given to it than to the tensile test.

Mr. Zugmayer believed that the tensile test frequently gave none other but theoretically defective results; he added that it had not the practical value which was attributed to it. A bending test required no special preparation; it could be carried out at any time and in any place, and always yielded a certain and constant result which could be checked. The original specimen remained, and it was possible to ascertain after the test was made whether the edges were cracked, whether the test piece was burnt, and so forth.

When therefore in the case of bars and plates both tests were specified, Mr. Zugmayer proposed the following: "If the bending test yielded good results and the tensile test insufficiently good results, acceptance was to depend upon a second bending test. If the tensile test was satisfactory, and not the bending test, acceptance was to be made also conditionally upon a second bending test. If the results of both tensile and bending tests were not good, the piece was to be rejected".

The first test to be carried out was, therefore, the bending test, the tensile test followed; when the bending test was not satisfactory a second one could be carried out after the tensile test.

It was desirable that the tests be carried out at the manufacturers works and be witnessed by both parties. When the bending test is unsatisfactory and when the manufacturers have no tensile testing machine, then only should the subsidiary tensile test be carried out elsewhere. Mr. Zugmayer believed that in acting thus much trouble and cost would be spared and at the same time there would be no suspicion in regard to the value of the material.

Mr. Wehrenfennig believed the specifications of the Austrian railways to be satisfactory. The Austrian works, however, asked that a higher allowance in weight than 3 per cent be granted for wide plates, and their request appeared justified under present conditions.

It was, on the other hand, greatly to the interest of the purchaser that the weight of such plates should not exceed a fixed limit, so that he be not called upon to pay for an unnecessary weight of copper; other conditions intervened also from the point of view of the use of the material, and, besides, the rolls could be made to turn out the required thickness throughout. Therefore the allowance of even the 3 per cent for wide plates had also its advocates.

Manufacturers should put down convex rolls for the manufacture of such plates.

Mr. Selve considered that the conditions in force with the Prussian railways were justified and of practical value; he, however, also referred to the allowance difficulty on weights and thickness in words similar to those used by Mr. Zugmayer.

For bars and plates, Mr. Selve was of opinion that bending and tensile tests, and especially the latter, should be maintained.

Mr. Guillemin remarked that at the present time in France the following of the specifications in force with the various Companies gave rise to no serious difficulty. He however shared the opinion expressed by Mr. Zugmayer, to the effect that owing to complications and even to impossibilities in the processes of manufacture, the allowances on the weights of tubular plates should be greater.

The figures proposed by Mr. Zugmayer and stated above might therefore be adopted.

He believed, on the other hand, that the tensile test should not be done away with, for bending tests did not replace tensile tests.

Mr. Breuil asked that the tensile tests should certainly be maintained, seeing that they gave, in a more complete way than the bending tests, all the required data as to the resistance and deformation characteristics of copper. Bending tests were hardly better than qualitative tests and their results, being difficult or interpretation, did not make it possible to introduce accurate values in the specifications.

Mr. Breuil added that, when carrying out tensile tests, the apparent elastic limit should be taken with a pair of compasses; this formed a useful reference for establishing the extent of cold working the metal has undergone.

If this were not done, the tensile test should be made only after annealing the copper to about 700 C. (1292° F.), in order to make it possible to arrive at a correct estimation as to the quality of the metal. Seeing that the rate of cooling after annealing had an influence on the metal structure, Mr. Breuil proposed to rapidly heat the test pieces to the stated temperature and quench them in water. In this way the tests would afford a better guide for the quality of the metal.

Mr. Breuil added further that the rapidity with which the tensile test was made had a certain influence on the breaking stress of copper. Although Martens was of opinion that this influence should be neglected, he nevertheless found that the stress was thereby increased by 2 per cent. According to Mr. Breuil, Mr. Ledoux found an increase of 6 per cent and recommended not to carry the test out rapidly, especially towards the end.

The hardness of copper could be determined by the Brinell ball-test or by compressing a small cylinder. In the case of cold worked bars, the cylinder would give an accurate idea of the malleability of the metal, simply by hammering it down.

For wire, bending round 90 degrees on both sides of the vertical, formed an excellent test which did not necessitate any complicated device.

If it is required to test wires by torsion, the moment at the elastic limit should also be recorded as in tensile tests; the maximum elastic moment was the angle of torsion at fracture to the unit of length.

Mr. Breuil advocated the tensile test of locomotive fire-box stay-bolts, when these were finished ready for use and at the temperatures they reach when in service.

In his opinion, repeated bending tests should also be made until fracture, with stay-bolts heated and held in place, exaggerating the bending action which they undergo in service.

In regard to tubes, it might only be necessary to cut a ring perpendicular to their axis, the ring to be opened out on a conical mandril; it should not tear until it has reached a certain diameter.

A test piece might also be taken lengthwise and another crosswise and straightened out, using a wooden mallet.

It might also be advisable to test the tubes or specimens at temperatures similar to those they have to withstand in service.

Query 7.

Have you any special proposals to make in the matter of fresh tests, modification of methods, or application to copper of test methods already followed for other material; or in regard to recording results and so forth?

Messrs. Glazebrook and Tomlinson had no proposal to put forward. They called attention to the researches made with reference to copper by several scientists, by Roberts-Austen among others, in connection with the alloys Committee of the Institution of Mechanical Engineers, and stated that further researches were in progress at the National Physical Laboratory on the effect of extreme cold on the resistance of copper to tensile stress.

Mr. Zugmayer recapitulated as follows the conditions which he deemed necessary:

a) Plates. The test piece over 10 mm ($^3/_8$ in) thick and having for width four times its thickness, annealed, should bend double without breaking.

Subsidiary tensile test of carefully machined and annealed test pieces, their angles to be slightly rounded off.

b) Bars. The annealed specimen to bend round 180 degrees without becoming damaged. Tensile test as above. The flattening down of a rivet head and threading should both be successful.

c) Wire. Should bend over and back, round 180 degrees, in the soft state, by means of two pincers.

d) Sheets. Should in the soft state bend over and back round a mandril having the thickness of the sheet; in the case of thin sheets under 2 mm (0·078 in.), two flat pliers should be used. They should take an edge without fracture when hammered down cold. The angles of the test piece to be rounded off. If necessary, a second bending test to decide.

e) Tubes and tube rings. To be flattened down in the soft state. To bend also round 20°. If the test is not satisfactory, a second one to decide.

The specimens are to be taken:

a) Plates. One tensile or bending test piece per plate, in the direction of rolling.

b) Bars. One for every 300 kg (660 lb.).

c) Wire. One for every 300 kg (660 lb.).

d) Sheets. One for eyery 300 kg (660 lb.).

e) Tubes. One for every 50 m (164 ft.) length; for rings, one for every 100 m (328 ft.) length.

Mr. Selve sent in proposals exactly similar to those of Mr. Zugmayer.

Mr. Wehrenfennig reported on the bending and tensile tests as follows:

It is advisable, for plates, to carry out especially the tensile test and the bending test; the first allowed of more accurate comparisons and the second approached more closely to the stress produced in the plates under service conditions.

In almost every case the results of the tensile test and of the bending tests corresponded with each other.

If the tensile test were carried out on one and the same machine, comparison was easier because the same rapidity could be worked to for tension; test pieces could always be had similar to one another. It must, of course, be taken for granted that the machine works accurately and that the records are taken with all desirable care.

By using one and the same tensile machine, care being given to the machining of the test pieces, these being always prepared in the same way, reliable results will be obtained. If different machines be used, they should be checked one with the other.

When preparing specimens for test, it is necessary to avoid transversal planing; it is preferable to use a milling machine. If, however, planing has already been resorted to, the specimens should be filed longitudinally. The specimens should not be taken from parts having been impaired locally, as, for instance, by stamping, etc. This remark is justified in that the effect of stamping of record numbers, firm's name, and so forth, made before machining, may, although the specimen has been made perfectly smooth, become visible thus showing that as those parts the metal was influenced locally; this is liable to react upon the result given by the tensile test.

Before cutting out the specimen, the part from which it is removed should be annealed, in order to counteract all possible influences of a mechanical order.

The bending test is no less useful than the tensile test, but it also requires minute care and exactly the same preparation; it should always be carried out in the same manner, in order that the results be always comparable to each other.

The bending tests should not be made by hand, but under a machine; care should be taken not to fracture the specimen.

When test specimens taken from copper bars have been turned in a lathe, the tool marks should be removed by filing.

Tests had been devised by the writer for arriving at the strength and stiffness of drilled and bored copper specimens for stay-bolts. They consisted in holding a copper specimen by the threaded end, the free end carrying a weight and being rotated. The number of revolutions causing fracture was recorded. These tests were not yet completed.

In regard to chemical composition, the writer was not able to formulate a personal opinion and referred back to Muspratts Chimie IV p. 1939, 4th edition.

Mr. Heckmann attached much importance to bending tests and to the exact measurement of the elastic limit.

Mr. Guillemin remarked that the conditions in which tensile tests were effected had a very great importance and a considerable influence on the results: He mentioned under this head the temperature of the specimens, the rapidity, and the duration of the tests.

It would be advisable to make a systematic investigation into the influence of these and to define in the specifications the precise conditions in which the tests should be effected in regard to temperature, rapidity and duration.

Query 8.

Have you any remarks to make as to the chemical composition the influence of impurities, the percentage of cuprous oxide, etc?

Messrs. Glazebrook and Tomlinson stated that copper containing arsenic entered into many mechanical applications; for instance in the manufacture of locomotive fire-boxes, stay-bolts, tubes, etc. Data on specifications are given further on.

Mr. Diller said that he never analysed copper and that he relied solely upon the results of electrical and physical tests.

Messrs. Zugmayer and Selve reported that a small percentage of arsenic (Mr. Z. = 0·3% and Mr. S. = 0·5%), of silver, cadmium, zinc, silicon is, if anything, of advantage; also of lead 0·15%, and phosphorus 0·1%. Oxygen up to 0·06% had no influence, but higher percentages were detrimental. Bismuth, antimony, nickel, tellurium and sulphur should be non-extant. It should be added that the latter elements have different effects according as they are reduced, or according as they are contained in combination or as oxides. If together their effect is different from the effect they have individually. In any case, their presence is dangerous and should be avoided. Thus, a low percentage of nickel has no influence, a notable percentage of arsenic is advantageous, but both these elements together are extremely detrimental.

Mr. Heckmann gave similar indications, and believed 0·02% silver, 0·15% lead, 0·1% phosphorus, 0·2% nickel, 0·1% oxygen could be admitted. Arsenic up to 0·75% had a favourable effect.

Mr. Heckmann stated that he found a copper containing both 0·2% nickel and 0·75% arsenic to show excellent results in various tests.

Mr. Wehrenfennig gave us no personal epinion in regard to chemical composition and referred to Muspratt's Chimie IV, p. 1938, 4th edition.

He said, it was very probable that the copper of fire-boxes of old manufacture was more able to withstand the influences of fire in service in the locomotives, than the present day copper; in some copper, recently purchased, a great difference is noticeable in regard to strength from the point of view of cracks, although there was but little difference in the chemical composition*).

It would therefore appear that the chemical composition has no particular influence on the resistance of copper for stay-bolts; it is rather to be supposed that the physical nature of copper, the state of its surface and the density of the metal, have the greatest influence in regard to resistance.

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*) Mr. Heckmann added at this point that formerly the fire-box plates were not annealed, but were worked up in their hard state as they left the rolls. At the present time they are thoroughly annealed to facilitate their bending.

As is well known, in some Railway Companies' Works the fire-box tubular plates are hammered in order to render them more durable. It is important to note that hammered copper tears very easily on bending, and the more easily, the harder the hammering and bending operations have been conducted.

Attention should be called in this connection to the observations made by the writer on locomotive boilers and which he put forward in „Eisenbahn Technik der Gegenwart" Vol. I. First Edition, p. 119; these deal with the influence of proportional absolute resistance and resistance to compression on the duration of the metal.

The writer noticed that copper stay-bolts almost invariably break along and inside the fire-box walls, rarely over their free length.

Copper stay-bolts almost always break on the inside of the fire-box; at that part the temperature is the highest and has a more rapid action on the resistance of the metal.

It might be well to remark here, added Mr. Wehrenfennig, that copper bars, on heating and cooling, expand both in length and thickness, a property which would tend to explain certain cracks in the fire-boxes.

It would be as well to study the different kinds of copper in regard to tensile stress and compression at different temperatures also to consider at different temperatures the density of the metal by using the Brinell and Leedwik tests, for, beside the tensile stress, elongation and striction, bending, resistance to compression density, and superficial resistance, have also an influence on the life of fire-box plates exposed to varying temperatures.

Such studies and others also are absolutely necessary to throw light upon the characteristics of copper.

Mr. Skinner replied: The question of impurities in copper, as determined by conductivity tests, has been studied by Addicks: "Transactions of the American Institute of Mining Engineers" Vol. 36. pp. 18 to 27.

The conductivity of copper is very greatly influenced by arsenic and phosphorus; these, in small proportions, have no otherwise detrimental effect. Conductivity is but little influenced by such impurities as antimony, bismuth, sulphur and oxygen which, however, in certain conditions are detrimental. Engineers and

chemists who are well informed on the matter require complete analyses in order to express their opinion; a long experience of the subject is necessary to decide fully upon what are the best refining processes for electrical work.

Mr. Skinner had not been able to find a good and rapid method to determine the percentage of cuprous oxide in copper; it appeared to him desirable that the Committee should give its attention to establishing such a method.

The mechanical properties of the copper used for electrical purposes, including telephonic lines and lines for current transmission, demanded at the present time more attention than did conductivity.

Rapid and reliable methods to determine fragility and hardness, and specifications stating the limits that can be adopted for the different mechanical properties, were extremely desirable. For example, large quantities of copper wire measuring 0·0031 to 0·0201 inch (0·78 to 5·63 mm) were used in the electrical industry. Imperfect annealing rendered this wire very fragile and hence winding was more difficult. Attempts had several times been made to arrive at the fragility by measuring elongation, but so far uniform and satisfactory results had not been obtained, the method of testing for elongation not being sufficiently developed; this however, was the best method known for recording fragility.

Much attention had been paid of late to the study of the annealing, at temperatures of 100° to 300° C. (222° to 572° F.), of copper which had been drawn down to a large extent, such as is now used in current transmission lines. A complete study of the effect of heat on the toughness of copper would be welcome and would yield invaluable information.

In the United-States, the copper works and the manufacturers of copper articles generally agreed together in the matter of the quality of the metal, the limit of impurity and so forth, the limit in question being determined by the use to which the metal had to be put; but no specification on the question had been published.

The heat coefficient, that is to say the variation of electrical resistance with the temperature should be determined and, if possible, the same figures should be adopted in the different countries.

The rules as to the specimens adopted in June 1907 by the American Institute of Electrical Engineers, give a tabular statement in regard to temperature coefficients, in which the figures are different from those adopted in 1893 by the same Institute.

Mr. Guillemin found the question to be much involved and added that it should be made clear by methodical tests.

Researches made recently established that occluded gases were in all the copper alloys used for engineering purposes and that these gases contained hydrogen, nitrogen, carburets, etc.

So far it would be difficult for a chemist to ascertain, whether the oxygen which he had measured in a given quality of copper existed as cuprous oxide or as occluded carbon oxide. Moreover, the influence of oxygen on the mechanical and electrical properties of copper was presumably not the same according as it existed as cuprous oxide or occluded gas.

Scientific research on the point would therefore be desirable.

Query 9.

Would you advise a meeting of the Committee? If so would you agree that a meeting take place in Paris in October?

All the members who reside outside France replied that they could not attend such a meeting.

Query 10.

Do you know scientists, or manufacturers, who are not members of the Committee, but who could put forward interesting information?

Messrs. Glazebrook and Tomlinson gave the names of Mr. Carpenter and Mr. Fitzpatrick, and also of the Gentlemen who took part in the discussion of the paper by Messrs. Carpenter and Edwards on copper-aluminium alloys.

Messrs. Zugmayer and Wehrenfennig mentioned Mr. F. Ringhoffer, of Prague-Smichow (Bohemia).

The latter also mentioned Mr. Chaudoir, of Simmering; Prof. Kirsch of Vienna; and Dr. Ludwik, also of Vienna.

Mr. Skinner gave the names of Mr. J. A. Capp, Engineer in charge of the tests, with the General Electric Co, Schenectady

N. Y.; Mr. John J. Carty, Chief Engineer, American Telegraph and Telephone Co, New-York City.

Mr. Skinner added that the would undertake with pleasure all tests that could be carried out at Pittsburg, or centralise all the information which the Committee would think it advisable to ask for, if a programme were set before him.

As was stated in the commencement of this paper, it was difficult for the Committee to arrive at a decision in so short a time.

It is hoped however that the readiness with which the various members have replied to the requests made by the President — who takes this opportunity to render them his thanks — affords a sign that an agreement will shortly be reached and that a complete report on a standard specification for the purchase of copper will be ready for the following Congress.

The President is of opinion that on that future date, or from now if it were preferred, the powers of the Committee should be extended to the various copper alloys: brass, gun metal and others.

Table I.

Copper wire for all purposes except electrical work.

<table>
<tr><td>Country</td><td colspan="3">France</td></tr>
<tr><td>Specification of</td><td>Artillery Depart.</td><td>North of France Railway Company</td><td>Navy Depart.</td></tr>
<tr><td>Date of publication</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>Chemical composition</td><td>Foreign elements
$< 0{\cdot}04\%$</td><td>—</td><td>—</td></tr>
<tr><td>Tensile test</td><td>$R = 22 = 13\ 97$ t per sq. in.
$A\ \% = 40$
For wire < 2 mm $= 0\ 078$ in. diameter
no tensile tests</td><td>$E\%$ variable with diameter
<table>
<tr><td rowspan="2">Diameter</td><td colspan="2">R</td><td colspan="2">$E\%$</td></tr>
<tr><td>Average</td><td>Minimum</td><td>Aver.</td><td>Min.</td></tr>
<tr><td>1·5 mm = 0·059 in.</td><td>45 = 28·57 t per sq. in.</td><td>40 = 25·40 t per sq. in.</td><td>2</td><td>1</td></tr>
<tr><td>4 „ = 0·157 „</td><td>40 = 25·40 „ „ „ „</td><td>36 = 22·86 „ „ „ „</td><td>3</td><td>2</td></tr>
<tr><td>5 „ = 0·197 „</td><td>35 = 22·22 „ „ „ „</td><td>30 = 19·05 „ „ „ „</td><td>5</td><td>4</td></tr>
<tr><td>6 „ = 0·236 „</td><td>30 = 19·05 „ „ „ „</td><td>25 = 15·87 „ „ „ „</td><td>6</td><td>5</td></tr>
<tr><td>11 „ = 0·433 „</td><td>25 = 15·87 „ „ „ „</td><td>20 = 12·70 „ „ „ „</td><td>15</td><td>12</td></tr>
</table></td><td>—</td></tr>
<tr><td>Bending test</td><td>—</td><td>5 bends</td><td>—</td></tr>
<tr><td>Winding test</td><td>—</td><td>—</td><td>Winding round a rod of same diam. as wire; straightened out, and wound inversely round same rod.</td></tr>
</table>

s.

	Great Britain
	North Eastern Railway
	—
ɔ	$0{\cdot}2 \leqslant As \leqslant 0{\cdot}5$
e, res s.	—
	—
ks ng	Test pieces taken in a strip $525 \times 62{\cdot}5$ mm $= 20{\cdot}68 \times 2{\cdot}46$ in., to be $37{\cdot}5$ mm $= 1{\cdot}47$ in. in length
in.	$R \geqslant 14$ t per sq. in. $E \geqslant 35\%$ on 4 in.
	Vire wound round cyl. mandril of 15 times the wire diameter
	—

Table III.

Countries	British
Specification of	
Date of publication	
Chemical composition	
Electrical resistance	
Remarks	
Tensile test	mm = 0.06 3 „ = 0.07 4 „ = 0.09 5 „ = 0.11 5 „ = 0.12) „ = 0.13) „ = 0.14 5 „ = 0.15 7 „ = 0.16
Bending test	

Copper plates for locomotive fire-boxes.

Table II.

Countries		Great Britain	Austria	Germany	France	Great Britain	Italy	Belgium
Specification of		Engineering Standards Committee	Austrian Railways	Railways	Railways	North Eastern Railway	Railways	Railways
Date of publication		June 6th 1907	—	—	—	—	—	—
Chemical composition		Class A, $Cu \geqslant 99\%$ $0{\cdot}35 < As < 0{\cdot}55\%$ Class B, $Cu \geqslant 99{\cdot}25\%$ $0{\cdot}25 < As < 0{\cdot}45$	Smelted Cu (= Pure $Cu + 0\,25\%\ As$) without addition of electrolytic Cu	1st quality copper	1st quality copper foreign element $\leqslant 0{\cdot}4\%$	$0{\cdot}2 \leqslant As \leqslant 0{\cdot}5$	Electrolytic copper excluded $0{\cdot}35 < As < 0{\cdot}55$ other elements, such as oxygen, not to exceed 0·75. Bismuth not tolerated	$0{\cdot}35 < As < 0{\cdot}55$ Density of copper 8·88. Allowance of 5% on weight of goods deducted from this density
Allowance on dimensions		—	—	—	+ 8 mm (0·315 in.) above, nothing below. A table gives allowances on thicknesses.	—	—	—
Tensile test	State of metal	Rough	Rough	—	Rough	—	—	—
	Type of test specimen	Length 20 cm = 7·87 in.	$l = 11{\cdot}3\sqrt{s}$	—	Length between gauge marks $L = \sqrt{66{\cdot}67\,S}$ S = section A table gives sizes according to thicknesses	Test pieces taken in a strip $525 \times 62{\cdot}5$ mm $= 20{\cdot}68 \times 2{\cdot}46$ in., to be 37·5 mm = 1·47 in. in length	—	—
	Results	$R \geqslant 22{\cdot}05 = 14$ t per sq. in. $E \geqslant 35\%$	$R \geqslant 22 = 13{\cdot}97$ t per sq. in. $E \geqslant 35\%$ $\Sigma \geqslant 40\%$	$R \geqslant 22 = 13{\cdot}97$ t per sq. in. $E \geqslant 38\%$ $\Sigma \geqslant 50\%$	$R \geqslant 20 = 12{\cdot}70$ t per sq. in. $E\% \geqslant 35$	$R \geqslant 14$ t per sq. in. $E \geqslant 35\%$ on 4 in.	$R \geqslant 22 = 13{\cdot}97$ t per sq. in. $E\% \geqslant 35$	Plates under 8 mm = 0·315 in. no tensile test. $R \geqslant 22 = 13\,97$ t per sq. in. for others. Rolled faces planed 1 mm = 0·039 in. and polished $E \geqslant 35\%$
Bending test	State of metal	Rough cold and hot	Rough cold and hot	—	Rough cold	cold	—	—
	Results	Bending at 180° no flaws nor cracks	Bending round mandril of same thickness For tickness above 10 mm = 0·393 in. cold bending round 30°; when hot bending right over. No cracks, etc.	Up to 4 mm, = 0·157 in. to bend cold and hot completely round mandril of d = twice thickness.	Strips 250 mm = 9·8 in. long, 40 mm = 1·57 in. thick, bent right over at both ends, in opposite directions, without cracks and other defects.	Strips $250 \times 12{\cdot}5$ mm $= 9{\cdot}8 \times 0{\cdot}49$ in. bent right over, without fracture	Bending test as in French Railways	Bending right over of strips taken in any direction, both cold and at a dark red heat, for plates where $l = 8$ mm $= 0{\cdot}315$ in. Bending round mandril of radius equal to halt thickness of plate both cold and at a dark red heat, for plates where $l = 8$ mm. Broken section to be pink, clean and silky
Proportion of tests		—	—	—	Tensile test: 1 per plate or per 500 kg (1000 lb.) of plates Bending test: as above Chemical analysis: 1 per 10 plates	—	—	If required: a stamping out test.

Table III.

Copper wire for electric conductors.

Countries	Great-Britain	France	France	France	British Post-Office	Norwegian Telegraphs	Dutch Telegraphs
Specification of	Engineering Standards Committee	Post and Telegraphs	—	Tramway Cos. Trolley wire	—	—	—
Date of publication	July 26th 1904	—	—	—	—	—	—
Chemical composition	—	—	—	—	—	—	—
Electrical resistance	Hard drawn: Wire 1 m = 39.37 in. long; weight 1 gr. = 0.002 lb. R. = 0.1539 Ohms, at 15.6° C. = 60° Fahr., extensively cold-worked wire = that which extends by 1% maximum before breaking Annealed: Same wire length and weight as above. R = 0.1508 Ohms, normal, at above temperature	Electr. Res. at 0° per km dia. Ohms 2 mm = 0.079 in. 5·3 2·5 „ = 0.098 „ 3·39 3 „ = 0.118 „ 2·36 3·5 „ = 0.138 „ 1·73 4 „ = 0.157 „ 1·33 4·5 „ = 0.177 „ 1·05 5 „ = 0.196 „ 0·85	In France annealed wire is tested electrically and for elongation. Electr. res. should be = 20.57 ohms. per km on the basis of 1 mm. = 0.039 in. wire, at 0° C = 32° Fahr. Elong. 10% minimum. Some authorities require 30% for wire above 2 mm = 0.079 in. in dia.	—	—	—	—
Remarks	Specific gravity 8.90 at 15° C. = 59° Fahr. Variation 0.00428 per deg. C for conductivity. Allowance: 2% on resist. and weight	—	—	*d* 8 mm = 0.315 in. total *R* 2000 kg = 4400 lb. *d* 9 mm = 0.354 in. total *R* 2480 kg = 5450 lb. *d* 10 mm = 0.394 in. total *R* 2980 kg = 6550 lb.	—	—	—
Tensile test	—	Variation of results with the diameter *d* *R* 2. mm = 0.079 in. 44.6 = 28.32 t p. sq. in. 2.5 „ = 0.098 „ 43.8 = 27.81 „ „ 3. „ = 0.118 „ 42.5 = 26.95 „ „ 3.5 „ = 0.138 „ 41.57 = 26.37 „ „ 4. „ = 0.157 „ 40.6 = 25.78 „ „ 4.5 „ = 0.177 „ — = — 5. „ = 0.196 „ — = —	—	—	*d* 1.6 mm = 0.063 in. *R* 105 kg = 231 lb. *d* 2.008 „ = 0.079 „ *R* 150 „ = 330 „ *d* 2.464 „ = 0.096 „ *R* 225 „ = 495 „ *d* 2.845 „ = 0.112 „ *R* 300 „ = 660 „ *d* 3.175 „ = 0.122 „ *R* 375 „ = 825 „ *d* 3.480 „ = 0.134 „ *R* 449 „ = 988 „ *d* 3.789 „ = 0.146 „ *R* 525 „ = 1155 „ *d* 4.015 „ = 0.158 „ *R* 600 „ = 1320 „ *d* 4.207 „ = 0.166 „ *R* 675 „ = 1485 „	—	—
Bending test	—	Bends vary in number with diameter	For annealed wire *d* 1. mm = 0.039 in. 16 bends over a round edge of 3 mm = 0.118 in. „ 1.2 „ = 0.047 „ 14 „ 3 „ = 0.118 „ „ 1.8 „ = 0.070 „ 8 „ 3 „ = 0.118 „ „ 2.5 „ = 0.998 „ 6 „ 3 „ = 0.118 „ „ 3. „ = 0.118 „ 5 „ 6 „ = 0.236 „ „ 4. „ = 0.157 „ 6 „ 10 „ = 0.393 „ „ 5. „ = 0.197 „ 5 „ 10 „ = 0.393 „ For hard wire *d* 2. mm = 0.079 in. 6 bends over a round edge 6 mm = 0.236 in „ 2.5 „ = 0.098 „ 5 „ 5 „ = 0 197 „ „ 3. „ = 0.118 „ 7 „ 10 „ = 0.393 „ „ 4. „ = 0.157 „ 5 „ 10 „ = 0.393 „ „ 4.5 „ = 0.177 „ 4 „ 10 „ = 0 393 „ „ 5. „ = 0.197 „ 4 „ 10 „ = 0.393 „	—	—	*d* 4·5 mm = 0.177 in. 5 bends over radius 10 mm = 0.393 *d* 3.3 mm = 0.122 in. 5 similar bends *d* 2·75 mm = 0.106 in. 5 similar bends	—
Twisting test	—	—	—	—	*d* 1.676 mm = 0.063 in. 35 Bends on 3 in. *d* 2.006 „ = 0.079 „ 30 „ „ 3 „ *d* 2.464 „ = 0.096 „ 25 „ „ 3 „ *d* 2.845 „ = 0.112 „ 20 „ „ 3 „ *d* 3.175 „ = 0.122 „ 32 „ „ 6 „ *d* 3.480 „ = 0.134 „ 30 „ „ 6 „ *d* 3.759 „ = 0.146 „ 28 „ „ 6 „ *d* 4.013 „ = 0.158 „ 26 „ „ 6 „ *d* 4.267 „ = 0.166 „ 24 „ „ 6 „	—	*d* 4 mm = 0.157 in. 20 bends on 150 mm = 5.9 in. tens. 20 kg = 44 lb. *d* 3 mm = 0.118 in. 15 on 75 mm = 2.95 in tens. 15 kg = 33 lb. *d* 2.5 mm = 0 098 in. 20 on 75 mm = 2.95 in. tens. 10 kg = 22 lb. *d* 2 mm = 0.079 in. 25 on 75 mm = 2.95 in. tens. 8 kg = 17 lb.
Winding test	—	Wire wound round cyl. mandril of 15 times the wire diameter	—	—	Wire wound round itself, 6 spirals whatever be the diameter	—	As under Britsh Post Office but 8 spirals

Post-Office	Norwegian Telegraphs	Dutch Telegraphs
—	—	—
—	—	—
—	—	—
—	—	—
—	—	—
3 in. R 105 kg = 231 lb. 9 „ R 150 „ = 330 „ 6 „ R 225 „ = 495 „ 2 „ R 300 „ = 660 „ 2 „ R 375 „ = 825 „ 4 „ R 449 „ = 988 „ 6 „ R 525 „ = 1155 „ 3 „ R 600 „ = 1320 „ 5 „ R 675 „ = 1485 „	—	—
—	d 4.5 mm = 0.177 in. 5 bends over radius 10 mm = 0.393 d 3.3 mm = 0.122 in. 5 similar bends d 2.75 mm = 0.106 in. 5 similar bends	—

rivets, etc.

France
Railways
—
...t quality. Foreign ele...
...mm = 0·0039 in. for... ...mm = 0·0078 in. for...
...ng tests per 500 kg =... ...ching tests on stay-bo...
Rough
...tween gauge marks L... ...p diam. = 2 mm = 0·07...
$\geqslant 23 = 14{\cdot}6\ t$ per s... $\geqslant 30$
...bar of d = 5 mm...

Table V.

Countries	
Specification of	
Date of publication	
Chemical composition	
Allowance on dimensions	
Quantity tested	
Stamping out test	Results
Flanging test	
Flattening down and Bending tes...	
Hydraulic test	

N...
...aximum w... ...am. = 2·29 side
Tensile t... per sq. ...
Tube len... down ...

Copper bars for locomotive stay-bolts, rivets, etc.

Table IV.

Countries	Great-Britain	Austria	Germany	France	Great-Britain	Belgium
Specification of	Engineering Standards Committee	Railways	Railways	Railways	North Eastern Railway	Railways
Date of publication	June 1907	—	—	—	—	—
Chemical composition	$Cu \geqslant 99{\cdot}25\%$ $0{\cdot}15\% < As < 0{\cdot}35\%$	Smelted Cu (pure Cu with 0.25% As) no addition of electrolytic Cu.	Cu of 1st quality	Cu. of 1st quality. Foreign elements $< 0{\cdot}4\%$	—	Cu of 1st quality. Density 8·88, Allowance $\pm 3\%$
Allowance on diameter	—	—	—	$\pm$ 0·1 mm = 0·0039 in. for stay-bolts, $\pm$ 0·2 mm = 0·0078 in. for other bars	—	—
Quantity examined	Up to 2% of each diameter	One test specimen per 200 or 300 kg = 440 or 660 lb.	—	Bending and testing tests per 500 kg = 1100 lb. Texture and punching tests on stay-bolt bars.	—	1% of the order for tensile tests
Tensile test — State of metal	Rough	Rough	Rough	Rough	—	—
Tensile test — Test piece	Length = 8 diameters*)	—	—	Length between gauge marks $L = \sqrt{66{\cdot}67}$ Central part turned to diam. = 2 mm = 0·078 in. below orig. diam.	—	—
Tensile test — Results	$R \geqslant 22{\cdot}05 = 14\ t$ per sq. in. $E\% \geqslant 40$	$R \geqslant 22 = 13{\cdot}97\ t$ per sq. in. $E\% \geqslant 35$ $\Sigma \geqslant 45$	$R \geqslant 23 = 14{\cdot}6\ t$ per sq. in. $E\% \geqslant 38$ $\Sigma \geqslant 45$	$R \geqslant 23 = 14{\cdot}6\ t$ per sq. in. $E\% \geqslant 30$	$R = 14\ t$ per sq. in., $E = 40\%$ (Specimens = 0·95 in.)	$R = 24$ kg $15{\cdot}24\ t$ per sq. in. $E = 24\%$ on 200 mm = 7·87 in.
Compression test — State of metal	Rough	—	Rough	—	—	—
Compression test — Test piece	Length 25 mm = 1 in.	—	H = twice thickness	—	—	—
Compression test — Results	Hammering on end down to 9·52 mm = 0·375 in. not to cause flaws or cracks	—	Flattened down $^1/_3$ height, no cracks	—	—	—
Bending test — State of metal Temperature	—	Rough, hot and cold	Rough	Rough	—	—
Bending test — Results	—	Bending round 180° without cracks	Round specimen, d = 30 mm = 1.18 in. l = 180 mm = 7·09 in. with fillet. Bent cold	Round specimen, 250 mm = 9·84 in. long. Bent cold, right over, to show no crack, defect, etc.	—	—
Bending test on threaded end	—	—	—	On rough metal, length = 200 mm = 7·87 in. Threaded 2 mm = 0·079 in. pitch, angle 60°, depth 1·3 mm = 0·051 in., in two operations (turning and threading). Hammerbent cold, the two ends parallel and distant from each other by diam. of piece. No cracks, defects, etc.	Bent double, piece 200 mm = 7·87 in. long, no cracks	Fracture after notch on edge to be rose-coloured, silky, fine grain.
Texture test	—	—	—	All bars notched at 50 mm = 2 in. from one end to a depth of 3 to 4 mm = 0·118 to 0·157 in. Bars broken at notch. To show homogeneous texture rose-colour tint, silky and fine grain.	—	—
Punching test	—	—	—	End proceeding from texture test. Punched in centre, hole 8 mm = 0·315 in. diam. and 30 mm = 1·181 in. deep, using conical punch (angle 24°); opened out up to entrance diam. 16 mm = 0·630 in. No crack, tearing effect, nor trace of oxide. Test can be carried to complete opening-out, when tearing effect to be in one place only.	—	—

*) In the case of a very small specimen, to take a 3 in. one, then $E \geqslant 45\%$.

Table V.

Weldless copper tubes for Locomotive boilers.

Countries	Gr. Britain	—	—	Gr. Britain	Belgium
Specification of	—	Austria	France	North Eastern Railway	Railways
Date of publication	—	Railways	Railways	—	—
Chemical composition	$Cu \geqslant 99$, $0{\cdot}35 \leqslant As \leqslant 0{\cdot}55\%$	—	First quality copper. Foreign elements $\leqslant 0{\cdot}4$	99·25% pure *Cu*	—
Allowance on dimensions	—	—	Length + 5 mm = 0·197 in. Diameter + 0·5 „ = 0·020 „ Thickness + $^2/_{10}$ „ = 0·008 „ with 0·6 „ = 0·024 maximum	Maximum weight: a) tubes $1^3/_4$ in. outside diam. = 2·29 lb. per foot. b) tubes 2 in. outside diam. = 2·64 lb. per foot	—
Quantity tested	—	—	Pressure = 1 per tube Bursting = 1 „ 100 tubes Upsetting = 1 „ 25 „ Flattening = 1 „ 100 „ Bending = 1 „ 25 „	—	—
Stamping out test — Results	Final diameter = $^1/_4$ larger than original diameter	Final diameter = 1·2 times original diameter	—	Tensile tests on whole tube annealed R per sq. mm $\geqslant$ 14 t per sq. in.; $E\%$ on 4 in. = 45·0	End of tube flattened down completely, cold, over length of 5 to 10 cm = 1·97 to 3·94 in., without any cracks. Length of tube bent, cold, until radius of bend measured internally = twice the outside diam. of the tube, without showing any cracks whatever
Flanging test	Flange = 40 tube diameters	8 mm = 0·315 in. flange	Metal in the rough, cold, flat flange, width = $^1/_2$ diameter, maximum = 25 mm = 1 in., at right angle, with rounding off on radius = thickness. No cracks or defects	—	—
Flattening down and Bending tests	Cold and hot. Flattened down completely, then bent over 180° in direction perpendicular to length	—	a) Cold, after annealing, double bending twice over b) The same, at cherry-red heat	Tube length 200 mm = 7·87 in. flattened down and bent duble without cracks	—
Hydraulic test	To withstand minimum pressure of 52—67 kg per cm² = 740—950 lb. per sq. in. NB. The same for weldless tubes for feed pipes; but the latter to be: $Cu > 91{\cdot}25$; $0{\cdot}25 < As < 0{\cdot}45$. No flange test. Hydraulic pressure test stated on ordering.	Pressure = 15 atm. = 213 lb. per sq. in.	During 1 minute: pressure $P = 800 \frac{e}{d}$, P in kg per cm², e and d in mm Maximum 25 kg = 355 lb. per sq. in.	—	During 1 minute $P = 770 \frac{\text{thickness}}{\text{diameter}}$ P = number of atmospheres, thickness and diameter in mm
Hot Bending test	—	Tubes hot, filled with sand, to bend round bar of d = 3 times outside tube diameter.	—	—	—
Bursting test	—	—	Tube length 1 m = 39·37 in. annealed to 450—500° = 842—932° Fahr., cooled in air, to undergo hydraulic pressure until bursting. Max. pressure 500 atm. = 7100 lb. per sq. in. R = load per mm² of original section $\frac{Pd}{2e}$. $R \geqslant 15$ kg No deformation until pressure = $^1/_5$ bursting pressure.	—	—
Curving test	—	—	Tube filled with rosin, curved cold over $^1/_4$ circumference r (curvature = 1·5 d of tube). No cracks or rents. Test to take at most two operations.	—	—

Pos	Gr. Britain	Belgium
—	rth Eastern Railway	Railways
—	—	—
—	99·25% pure Cu	—
—	eight: a) tubes $1^3/_4$ in. outside lb. per foot. b) tubes 2 in. outdiam. = 2·64 lb. per foot	—
—	—	—
—	ests on whole tube annealed R mm $\geqslant$ 14 t per sq. in.; $E\,\%$ on 4 in. = 45·0	End of tube flattened down completely, cold, over length of 5 to 10 cm = 1·97 to 3·94 in., without any cracks. Length of tube bent, cold, until radius of bend measured internally = twice the outside diam. of the tube, without showing any cracks whatever
	—	—
	gth 200 mm = 7·87 in. flattened and bent duble without cracks	—
	—	During 1 minute $P = 770 \frac{\text{thickness}}{\text{diameter}}$ P = number of atmospheres, thickness and diameter in mm
	—	—

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VIII 10

ON IRREGULAR STRAINS DUE TO THE NON-HOMOGENEITY OF MATERIALS.

By Dr. techn. **A. Leon**, of Vienna.

(From Mitteilungen des Mechanisch-Technischen Laboratoriums der k. k. Technischen Hochschule, Vienna. Vienna 1908: Lehmann & Wentzel.)

Translated from the German by Dr. H. Borns, of London.

The following is a summary of the results of mathematical investigations concerning the irregular strains, which arise in elastic bodies, owing to the presence of rigid or elastic enclosures and of hollow spaces, as well as superficial flaws of various kinds. The accepted law of elasticity is Hooke's law in its extended form, i. e., the proportionality of stress and strain under linear (unidirectional) stress and the principles of the superposition of strains in two or three dimensions.

It results that irregular strains are set up chiefly in a zone whose thickness is the diameter of the enclosure or cavity causing the disturbance; the irregular strains are small outside that zone and vanish rapidly at increasing rate with increasing distance. The irregular strains are hence purely local. They are greastest at the boundary (or in its immediate vicinity) where, according to the shape and kind of stress, and according also (though not in all cases) to the ratio of longitudinal extension to lateral contraction (Poisson's ratio), a very important increase in the strains may be set up.

The results of the enquiry into the irregular strains have experimentally to be verified by breaking tests. In the case of brittle materials (glass, e. g.) in which the limit of elasticity lies

near to the spot of fracture, the verification will be direct. In plastic materials, especially in iron, the conditions are quite different. The elastic limit lies considerably below the tensile strength, having less than half that value in weld steel, and a little more than half of it in ingot iron and mild steel. The limit of elasticity and of proportionality is followed by the yield point, whose external characteristic is the incipient marked elongation without corresponding increase of stress, and whose internal characteristics are molecular changes, changes in the structure. This elongation, which accompanies a certain stress, and the already mentioned property that the irregular strains are merely local in nature, effect a balance in the strains when the yield point load is reached.

Owing to this circumstance the irregular strains cannot be demonstrated in ingot iron and weld steel by the ordinary methods of testing. When we take into consideration, however, that with continuous alternations of equal tension and compression stresses, the breaking strength is approximately reduced down to the elastic limit, because on exceeding that limit, tension causes a permanent elongation and pressure a permanent compression, and that the material cannot bear this change of permanent elongation and compression, while the deduced strains are valid up the elastic limit, we may assume that the appearance of increased strains due to flaws in the cross-section and to the enclosure of foreign materials might be demonstrated, with the aid of suitable experiments, also for iron and for ductile materials in general.

Many an unexpected breakdown occurring in parts of machinery after long duty might be explained on these grounds.

The following paragraphs briefly state the results of the deductions:

In a body of infinite extension in two directions (a plate) originally under a uniform, linear stress (i. e. a stress acting in one direction only), a cylindrical hole, circular in section, will cause increases of strain which may rise to 200%. The circumferential strains on the edge of the hole assume values varying from $-p$ to $+3p$. These increased strains are independant of the value of Poisson's ratio.

When the unperforated surface is uniformly stressed in all directions by the same force p, a hole will produce circumferential strains of the order $2p$. The increase in the strains hence amounts to 100% and is again independent of the elastic coefficients.

In bodies not of surface character, but of infinite extension in all directions of space, a cylindrical bore right through will cause equal strains in all the directions of sections at right angles to the axis of the cylinder. With unidirectional stresses these strains will have the maximum value 3 p, with stresses in the directions of the cross-section the maximum value 2 p. In the latter case no elastic forces will be set up in the direction of the axis of the cylinder; but such forces will arise in the former case, and the range of their value will be $\pm$ 2 p/m (where m is Poisson's ratio). When m = 2, their value will be p; m = 3, value 0·67 p; m = 4, value 0·50 p; m = 5, value 0·4 p; the absolute values of the elastic forces in the direction of the axis of the cylinder will hence decrease with increasing m.

When the perforations are not circular, but drawn out in a direction normal to the stress at action, the increased strains may attain multiples of the values stated. When the original stress is linear, sharp cuts in the direction of the force will hardly exercise any disturbing influence at all.

In surfaces whose rectilinear edge is interrupted by a semicircular notch, the strains at the edge of this notch will vary between 0 and 2 p, when p is the stress acting upon the body, in the undisturbed condition, in the direction of the edge.

When the body is not a surface, but of great (infinite) thickness, this distribution of the strains in the notches as just described will not be much altered. We have in addition, however, at right angles to the cross-sections and in the direction of the axis of the notch, strains whose magnitude will be $\pm$ p/m in the shell limiting the semi-cylindrical notch. For m = 2, they will be 0·5 p; for m = 3, 0·33 p, for m = 4, 0·25 p; for m = 5, 0·20 p, again decreasing with increasing values of m.

When a body originally under the linear stress p contains a spherical cavity, the irregular strains will have the limiting values: for m = 2, + 2·17 p and — 1·17 p; for m = 3, + 2·06 p and — 0·75 p; for m = 4, + 2·02 p and — 0·59 p; for m = 5, + 2·00 p and — 0·5 p. For the usual values of m the strains may hence be augmented by 100 % and more, and they will decrease with increasing m.

In a body of the nature of a surface of infinite extension, originally under linear stress, a circular, almost rigid enclosure

will produce increases in strain which, for m = 2, will amount to 47%; for m = 3, to 50%; for m = 4, to 53%; for m = 5, to 55% (and for m = ∞, to 67) %. The here indicated maximum values are those arising in the boundary common to the two bodies and they affect therefore the adhesion between the two bodies. When the enclosures are more difficult to strain than the material, it may indeed happen that the strains in the material may still exceed the maximum adhesion strains.

When the original stress acts uniformly in all directions of the central plane, the increase in the strains will amount, for m = 2, 3, 4, 5 (∞) to 33, 50, 60, 67 and (100) per cent.

In bodies not of surface nature, but of infinite extension in all directions, a continuous enclosure forming an almost rigid circular cylinder, will, with originally linear stress p, cause increases in the strains amounting for m = 2, 3, 4, 5 (and ∞) to 50, 47, 53 (and 67) %; there will further be normal axial strains of magnitude, p, 0·4 p, 0·25 p, 0·18 p (and 0) for m = 2, 3, 4, 5 (and ∞).

When the original stress is not unidirectional, but acts uniformly in all directions of the cross-sections, the strains will be increased by 0, 33, 50, 60 (and 100) % respectively for m = 2, 3, 4, 5 (and ∞). Normal axial strains will be absent.

When the stresses act in all directions in space, the strains will be raised by 0, 25, 40, 50 (and 100) % for m = 2, 3, 4, 5 (and ∞); the axial strains in the body will be constant and equal to p, those in the rigid enclosure will be very (infinitely) large.

When the stress acts only in the axial direction, small radial and peripheral strains will result in the direction of the planes of the cross-sections.

Within elastic enclosures forming circular cylinders, the strains will always be distributed according to a straight line law, when the stress-strain conditions are uniform, as they will be in bodies which are either practically surfaces or very (infinitely) thick.

In a surface-body whose straight-line edge shows a semicircular, almost rigid enclosure, the maximum strains will be set up at the edge itself and will amount to an increase of 80%.

A spherical, almost rigid enclosure within a body of infinite extensions in all directions under originally linear stress will produce increases in the strains amounting to 100, 93, 96, 100 (and

125) %, for m = 2, 3, 4, 5 (and ∞); with uniform stress conditions the increases will amount to 50, 71, 88, 100 (and 163) %. When the stress p acts in all directions, the disturbances will amount to 0, 50, 80, 100 (and 200) %.

Within a spherical elastic enclosure, the strains due to the stresses to which the body is submitted will be distributed according to a straight-line law.

A spherical enclosure of iron within a mass of concrete of infinite dimensions will raise the strains by 88, with original unidirectional stress, when we assume that the elastic moduli of the two materials are in the proportion: $E_1 : E_2 = 15 : 1$, and that the Poisson ratio for iron is $m = 4$, and for concrete $m_2 = 5$. By superposition we find increases of 89 and 89·4 respectively for stresses p acting in two or in three chief directions.

When however, $E_1 : E_2 = 10$, $m_1 = 4$, $m_2 = 5$, the maximum increase in strain will be 82% with originally unidirectional stress p. When the p act in two or three chief directions, the disturbances in the strains will amount to 83 and 84%.

A circular enclosure of iron within a plate of concrete of moderate thickness will raise the strains by 49% maximum, with originally linear stress, if $E_1 : E_2 = 15$, $m_1 = 4$, $m_2 = 5$, where E_1 and m_1 are the elastic coefficients of the enclosure (iron) and E_2 and m_2 those of the body (concrete). By superposition we find increases in the strains of $49 + 11 = 60$% for stresses acting in all the directions of the central plane.

When however $E_1 : E_2 = 10$, $m_1 = 4$, $m_2 = 5$, the maximum strain increase will be 47% for originally unidirectional stress, and it will be $47 + 10 = 57$%, if the stress act in all the directions of the central plane.

Taking $E_1 : E_2 = 15$, $m_1 = 4$, $m_2 = 5$ ($E_1 : E_2 = 15$, $m_1 = 4$, $m_2 = 5$), a cylinder of iron of infinite length embedded in a mass of concrete will, with originally unidirectional stress, raise the radial strains by 56 [64]%. The strains in the axial direction may amount to 0·13 p [0·22 p] in the concrete, and will have the constant value — 2·55 p [— 1·56 p] in the iron, etc.

In general:

Enclosures of any kind will (as long as their dimensions are small by comparison with the dimensions of the body, always call forth increases in the strains of the material, and thus a

diminution in the strength of the material, whether the enclosure be more easily deformed than the material or not. These increases in the strains are greatest within the elastic range, and they diminish rapidly when permanent deformations occur; they are hence scarcely observable in the breaking load of materials which bear permanent distortions. With enclosures which are more easily deformed than the material (when the enclosures have in general smaller moduli of elasticity) or with flaws in the cross-section (holes, blisters, notches), the maximum strain is set up at the surface of the enclosure or of the cavity. With enclosures which are more difficult to deform than the material (with "hard" enclosures), the greatest strains will be set up at right angles to their surfaces. In both cases the maximum strains will be set up in the direction of the undisturbed elastic forces.

The formulae for rigid enclosures do not always give the greatest strains for "hard" enclosures.

The greatest danger of a fracture will, to judge by all the hypotheses commonly made in this connection, not be at the spots of greatest disturbance in strain, but always in their immediate vicinity.

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IX4

INFLUENCE OF REPEATED LOADING UPON THE ADHESION BETWEEN CONCRETE AND IRON, OF BRIGHT, AND OF RUSTY SURFACES.

By Professor **Bernhard Kirsch,** Vienna.

Translated from the German by Dr. H. Borns, London.

A summary of the results of these experiments, which should be regarded as preliminary to a series of more comprehensive researches, was published in the „Österr. Wochenschrift für den öffentl. Baudienst“, 1909, No. 17. The members of the Copenhagen Congress will be interested in the chief results, and I may be permitted to give an outline of the investigation.

Bars of 20 mm thickness were fixed in concrete, in cubes of 20 cm edge, altogether 144 separate pieces, three of the same kind in each case. Before the adhesion tests commenced, the irons had been submitted to previous loads, in the same sense as afterwards, the pressure being applied axially to the iron. The number of times these preliminary loads were applied did not exceed fifty, because I assumed that any loosening of the iron in the concrete would, if at all noticeable, become apparent already after a few applications. My object was moreover to ascertain, whether previous loading would have any effect at all, rather than to study the influence of the number of applications of the previous loads.

The cements were a Portland cement and a slag cement, both slow-setting, of constant volumes, and of a tensile strength, respectively crushing strength, of 24 and 340 kg per cm^2, after four weeks.

The sand briquette mixture was prepared in the proportion 1 to 3.

The previous load was 150 kg on an adhesion surface of 125 cm^2.

The mortar was not rammed down, but only well distributed with the aid of a pestle. The adhesion strengths are hence very

low in their absolute values, which may be considered as a lower limit, such as is rarely to be met with in practice. The values appear suited, however, for the purpose of comparison.

The tensile strengths stated were determined with the same cubes (of 20 cm edge) after the irons had lost their adhesion. The irons remained in the cube while the pressure was applied to one of the sides.

Adhesion in kg per cm^2.

Cement		Portland Cement			Slag Cement		
Number of Previous Loads		0	10	50	0	10	50
1 month old	bright	8·36	7·26	10·11	4·11	6·40	6·64
	rusty	8·57	7·61	8·36	3·33	6·28	4·98
3 months old	bright	13·27	6·23	13·58	7·82	10·06	7·78
	rusty	8·78	8·37	7 01	6·50	6 72	5·33
Means		9·75	7·37	9·77	5·44	7·39	6·18

The mean crushing strengths were:

	Portland Cement	Slag Cement
after 1 month	106·5 kg/cm^2	58·1 kg/cm^2
„ 3 months	125·8 „	75·1 „

It would therefore result:

1. That repeated loads of 1·2 kg/cm^2 do not produce any alteration in the adhesion, neither with the Portland cement nor with the slag cement.

2. That rusty surfaces impair the adhesion, rather more in the case of the slag cement than of the Portland cement.

These diminutions in the adhesion amounted to:

after 1 month	with	Portland cement	4·5 per cent
„ 1 „	„	slag cement	15·0 „ „
„ 3 months	„	Portland cement	27·0 „ „
„ 3 „	„	slag cement	27·7 „ „

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X3

ON ACCELERATED TESTS OF THE CONSTANCY OF VOLUME OF CEMENTS.

Report presented by **Bertram Blount**, F. I. C. London, Chairman of the Committee 32.

The Committee appointed for the solution of Problem 32 „on accelerated tests of the Constancy of volume of cements" consisted of the following members.

G. Greil, Baurat im Stadbauamt, Wien (Austria),

Th. Pierus, Ingenieur, Zementwerks-Direktor, Wien (Austria),

E. Hiertz, chef de service de la Société Cockerill, Seraing (Belgium),

M. Petersen, Ingenieur der Dänischen Staatsprüfungsanstalt, Kopenhagen (Denmark),

Bertram Blount, Chemical Laboratory and Testing Works, London (Great Britain),

R. Curling Styles, Chemist to the Associated Portland Cement Manufacturers Ltd., Watford, Herts (Great Britain),

E. Leduc, chef de section au Lab. du Conservatoire des Arts et Métiers, Paris (France),

F. M. Meyer, Fabriksdirektor in Malstatt (Germany),

F. Schott, Direktor der Portlandzementfabrik, Heidelberg (Germany),

L. Bienfait, Ingenieur, Mitinhaber der Materialprüfungsanstalt, Amsterdam (Holland),

D. von Nagy, Professor am kgl. Polytechnicum, Budapest (Hungary),

J. Zhuk, Ingenieur der Versuchsstation, Budapest (Hungary),

O. Rebuffat, Dr., Professeur et Directeur du Cabinet du Chimie à l'Ecole royale supérieure Polytechnique (Italy),
O. Carlsen, Direktor der technischen Schule, Bergen (Norway),
A. Baykoff, Professeur de la Polytechnique, St. Pétersbourg (Russia),
O. Blaese, Chemiker, Zementfabrik, Port Kunda (Russia),
E. Schwarz, Chimiste, Fabrique de Cements, Noworossiisk (Russia),
V. Tagueef, Ingénieur au Lab. méc. à l'Inst. des voies de comm., St. Pétersbourg (Russia),
R. W. Lesley, President American Cement Co., Philadelphia (United States),
S. R. Newberry, Manager Sandusky Portl. Cement Co., Sandusky, Ohio (United States).

A meeting of the Committee was held at Brussels on January 26th 1903, which was attended by the members mentioned below:

Bertram Blount (Chairman), *E. Hiertz, Mayntz Petersen, R. Curling Styles, E. Leduc, L. Bienfait.*

At this meeting it was decided that some form of hot test should be adopted as a standard accelerated test for the constancy of volume of cement. Experiments were to be made on samples procured from the various countries represented to decide the best temperature for the test and the most suitable means of measuring the expansion of the test pieces. A representative of each country was chosen to carry out the experiments; the following is a list of the members invited to undertake this work.

Alfred Greil, Austria, *Mayntz Petersen,* Denmark, *R. Curling Styles,* Great Britain, *E. Leduc,* France, *F. Schott,* Germany, *L. Bienfait,* Holland, *Des. Nagy,* Hungary, *O. Carlsen,* Norway, *E. Schwarz,* Russia, *R. W. Lesley,* United States.

A detailed programme of the methods of carrying out the tests was given in Appendix I to the Brussels Congress report[1]).

A report of the resolutions formulated by the meeting at Brussels was communicated to each member of the Committee, and a copy of the programme of work with an invitation to cooperate

[1]) Copies of the report presented to the Brussels Congress and containing the above appendix can be obtained on application to the General Secretary of the Intern. Association, Vienna, $II/_2$ Nordbahnstr. 50.

was sent to the members chosen by the Committee to carry out the experiments.

Requests were sent to members of the Committee and others for samples of cement on which to experiment. The samples were to be (1) sound, (2) doubtful and (3) unsound. It was arranged that portions of each sample should be distributed to those members of the Committee who were willing to undertake the work of experimenting.

A letter was adressed to M. Rebuffat asking him to investigate the nature of the substances which tend to cause the expansion of cement with the view of arriving at a means of identifying and determining them by proximate analysis or microscopically.

Working on the lines laid down in this programme Mr. Leduc (France), Mr. *Bienfait* (Holland), Mr. *Schwarz* (Russia), Mr. *Petersen* (Denmark) and Mr. *Styles* (England) have carried out a series of tests according to the programme and have communicated the results of their experiments. These results are given in appendix II of the above mentioned Brussels Congress report.

On examining the results given in these tables it is evident that the ordinary cold water pat test at 28 days is not capable of detecting with certainty a cement known to be unsound and that it fails completely to detect a cement of doubtful soundness.

It is also apparent that there is much difficulty in obtaining concordant results with the Bauschinger Apparatus used by different operators. Apart from possible errors of manipulation this difficulty may well be caused by slight movement of the small metal plates inserted at each end of the test piece, between which the measurement is made. If the cement is expansive a displacement of these plates is rendered more probable and the difficulty of obtaining concordant results will be increased.[1])

The Le Chatelier test, on the other hand, gives results which are fairly concordant for different operators. Such divergencies as exist may reasonably be attributed to the fact that the samples were not all tested at the same time, and however carefully they were packed and stored may have become slightly aerated in some cases and thus made less expansive. It is also clear that tests at 15^0 C. and at 50^0 C. do not suffice to detect a doubtful or unsound

[1]) The metal plates should be set in with cement known to be absolutely sound, not necessarily with the cement to be tested.

cement with certainty, but that when the test is carried out at 100° C. as originally prescribed by Le Chatelier, it is easy to detect even a doubtful cement whereas a sound cement withstands the test perfectly, expanding to the extent of only a few millimetres.

The behaviour of the three samples specifically referred to in the Brussels Congress Report is typical of that of the various other samples examined by different members of the Committee. In all, five sound samples, five doubtful samples and four unsound samples were submitted to tests for constancy of volume. Without exception the cold pat test at 28 days was inadequate to detect with certainty doubtful samples or even samples known to be unsound. The tests at 50° C. sufficed to detect samples thoroughly unsound but could not be relied on to detect doubtful samples. The only perfectly reliable tests were those at 100° C.

Since the Conference in Brussels and the report dated 24th Decembre 1903 no work has been officially undertaken by the Committee in its corporate capacity. Mr. Schwarz has however been good enough to communicate results obtained by tests continued over a long period by the Bauschinger apparatus. A copy of Mr. Schwarz's figures is appended. They constitute a useful addition to the work already reported which relates to shorter periods. His comments are made as an individual member of the Committee.

The question of the constaney of volume of cements has now been advanced to a point where a definitive conclusion can be stated. The experiments carried out under the auspices of Committee No. 32 showed that an accelerated test at a high temperature could be fulfilled without difficulty by modern cements carefully manufactured and of high quality. It also showed that cements of doubtful quality were not casily distinguished from those which were free from all defect except by a high temperature test. All cold water tests and hot tests which were simply qualitative were found to be inadequate. Nothing which has occurred since the date of the Committeés report has tended to invalidate this conclusion, but a good deal has happened to confirm it. The accelerated hot test, at first strenuously resisted by manufacturers, has been accepted unreservedly in England. The British Standard Specification now requires that the expansion of a Le Chatelier test piece shall not be greater than 10 mm after the cement has

been aerated for 24 hours and 5 mm after the cement has been aerated for 7 days. This test is complied with habitually, and many cements are so free from expansion that these maximum limits are regarded by many as unduly high. During the early stages of the enquiry which preceded the conclusion of the British Standard Committee some doubt was expressed as to whether the Le Chatelier apparatus was suitable for comparatively rough use, such as that to which it would be subjected at a cement works or by the ordinary engineering staff on a large constructional undertaking. Experience has shown that no such difficulty occurs. As a natural result the Le Chatelier test is established in England as the standard method with which makers, users and engineers are satisfied.

In view of these facts it appears desirablet hat the Le Chatelier method for determining constancy of volume of cement should be adopted by the International Society as its standard method, and the following proposal is laid before the Congress:

"That the Congress decides to recommend the "method of Le Chatelier as the standard accelerated test "for the constancy of volume of cements. The method is "to be carried out as follows:

Le Chatelier Tests.

"The cement is gauged and filled into the mould on a plate "of glass, the edges of the mould being held together. When "the mould has been filled it is covered with a plate of glass "held down by a small weight, and the whole is immersed in "water at 15⁰ C. for 24 hours. Any tie or band which has been "used to keep the edges of the mould together during setting is "then removed. The distance between the indicator needles is "measured and the mould is placed in cold water which is raised "to a temperature of 100⁰ C. in the course of half an hour and "is kept boiling for 6 hours. The mould is removed from the "water and after it has cooled the distance between the indicator "needles is again measured. The difference between the two "measurements represents the expansion of the cement. This "must not exceed 10 millimetres when the cement has been "aerated for 24 hours, and 5 millimetres when the cement has "been aerated for 7 days."

Long Period Tests made by Mr. Schwarz.

Bauschinger tests.

Expansion of a bar 100 mm in length after being kept under water at 15° C. stated in units of $^1/_{100}$ mm.

Cement I			Cement II			Cement III		
Days	Set under water	Set in air	Days	Set under water	Set in air	Days	Set under water	Set in air
161	2	1	161	12	11	161	25	21
168	2	2	168	12	11	168	25	21
175	2	1	175	12	12	175	26	22
182	2	1	182	12	12	182	25	22
189	2	1	189	12	12	189	26	22
196	2	1	196	12	12	196	26	22
203	2	1	203	12	12	203	25	22
210	2	1	210	12	11	210	26	22
217	2	1	217	12	12	217	26	23
224	3	1	224	12	12	224	26	22
231	3	1	231	12	12	231	26	22
238	3	1	238	13	12	238	26	22
245	3	1	245	13	12	245	26	23
252	3	1	252	13	13	252	26	23
259	3	1	259	12	12	259	27	23
266	3	1	266	13	12	266	27	23
273	3	1	273	13	12	273	26	23
280	2	1	280	13	13	280	27	23
287	3	1	287	13	12	287	27	22
294	3	1	294	12	12	294	26	22
301	2	1	301	13	12	301	26	23
308	2	1	308	13	12	308	26	22
315	2	2	315	13	12	315	26	23
322	2	3	322	13	13	322	27	23
329	2	2	329	13	12	329	26	23
336	2	2	336	13	12	336	27	26
343	2	2	343	13	12	343	26	24
350	2	1	350	13	12	350	26	23
357	1	2	357	13	12	357	26	23
364	1	1	364	13	12	364	27	23
582	2	1	580	13	13	579	27	24

Bauschinger tests.

Expansion of a bar 100 mm in length after being kept under water at 15° C. stated in units of $^1/_{100}$ mm.

Cement II'			Cement III'			Cement I^A		
Days	Set under water	Set in air	Days	Set under water	Set in air	Days	Set under water	Set in air
119	19	14	119	18	16	77	7	4
126	20	14	126	20	16	84	7	4
133	20	14	133	19	17	91	7	5
140	20	14	140	19	17	98	7	5
147	19	14	147	20	16	105	7	5
154	19	14	154	20	16	112	7	5
161	19	14	161	19	16	119	7	5
168	19	14	168	18	16	126	7	5
175	20	14	175	20	16	133	8	5
182	20	14	182	20	16	140	8	5
189	19	14	189	18	17	147	8	5
196	20	14	196	19	18	154	8	6
203	20	14	203	19	17	161	8	6
210	20	14	210	21	17	168	8	6
217	20	15	217	21	17	175	9	6
224	20	15	224	19	17	182	9	6
231	20	14	231	19	17	189	9	6
238	20	14	238	19	17	196	9	6
245	20	14	245	19	17	203	9	6
252	20	14	252	19	17	210	9	6
259	21	14	259	19	17	217	9	6
266	20	14	266	19	17	224	9	7
273	21	14	273	19	17	231	9	7
280	20	14	280	19	17	238	9	7
287	21	14	287	19	17	245	9	7
294	20	15	294	19	16	252	9	7
301	22	15	301	19	17	259	9	7
308	21	15	308	19	14	266	9	7
315	21	16	315	20	18	273	9	8
322	22	15	322	19	17	280	9	8
329	21	16	329	20	17	287	9	8
336	22	16	336	19	16	294	9	8
343	23	16	343	20	17	301	10	8
538	24	18	539	21	17	493	11	11

Bauschinger tests.
Expansion of a bar 100 mm in length after being kept under water at 15° C. stated in units of $^{1}/_{100}$ mm.

Cement 2^A			Cement 3^A		
Days	Set under water	Set in air	Days	Set under water	Set in air
161	21	16	161	22	16
168	21	17	168	21	16
175	22	17	175	22	16
182	22	17	182	22	16
189	22	17	189	22	16
196	22	17	196	22	16
203	22	17	203	22	16
210	22	18	210	22	16
217	23	17	217	22	17
224	22	18	224	22	17
231	23	18	231	22	17
238	23	18	238	23	17
245	23	19	245	23	18
252	23	18	252	23	18
259	23	19	259	23	17
266	23	19	266	23	18
273	23	18	273	24	18
280	23	18	280	24	18
287	23	18	287	23	18
294	24	18	294	23	17
301	23	19	301	23	17
308	23	18	308	23	17
315	23	18	315	24	19
322	23	18	322	24	16
329	23	18	329	23	19
336	23	18	336	23	17
343	23	18	343	23	17
350	21	18	350	23	18
357	22	18	357	23	17
364	21	18	364	23	18
587	24	19	586	23	18

Results of the Le Chatelier and Hot Pat tests of Cement 3A after aeration at the ordinary temperature.

Period of Exposure Days	Le Chateliér Test at 100° C.	Hot Pat Test
0	52	Much cracked
3	45	One crack at the edge
5	42	One slight at the edge
7	38	"
10	28	"
12	27	Sound
14	24	"
17	17	"
19	16	"
21	11	"
24	10	"
26	10	"
31	8	"
33	7	"
35	9	"
38	5	"
40	7	"
46	1	"
48	4	"
50	1	"
53	1	"

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

X4

ON RAPID METHODS FOR DETERMINING THE STRENGTH OF HYDRAULIC CEMENTS.

Committee-Report presented by Dr. **Fr. Berger,** Vienna.

Together with appendices by Mr. L. Deval, of Paris, and Mr. Alf. Greil, of Vienna, respectively.

Translated from the German Original by A. R. Liddell, Charlottenburg.

After the death of Prof. L. von Tetmajer, of Vienna, and Prof. A. Cossa, of Turin, M. F. Behrmann of Riga and the retirement of Mr. D. Wassenko and Mr. S. Drouginine, of St. Petersburg, the Committee included the following members:

Chairman: Dr. *F. Berger,* k. k. Sektionschef, Stadtbaudirektor a. D., Vienna, VII., Schottenfeldgasse 37;

Members: *Camerman E.,* Chef du Service des essais des chemins de fer de l'Etat Belge, Brussels, 31, Square Gutenberg;

Berg D., Director of the Aalborg Portland-Cement Works, Aalborg (Denmark);

Heintzel C., Dr., Chemist, Laboratorium für Zementindustrie, Lüneburg (Germany);

Michaelis W., sen., Dr., Cement-Technicist, Berlin NO 18, Friedrichsstraße 19 (Germany);

Schott F., Director of the Portland-Cement Works, Heidelberg (Germany);

Ewing J. A., Prof., F. R. S. Engineering Laboratory, Cambridge (England);

Candlot E., fabricant de ciment Portland, Paris, 18 rue d'Edimbourg (France);

Mesnager A., professeur à l'École des ponts et chaussées, ingénieur en chef des ponts et chaussées, Paris, 1, 182, rue de Rivoli;

Feret R., chef du Laboratoire des ponts et chaussées, Boulogne-sur-mer (Pas de Calais, France);

Bienfait L., Ingenieur, Testing-Establishment for Building-Materials, Amsterdam, Da Costakade 104 (Holland);

Morris, Dr., Chief Chemist to the Aktiengesellschaft "Christiania Portland-Cementfabrik", Christiania (Norway);

Greil A., Baurat, Vorstand der städtischen Materialprüfungsstation, Vienna, Rathaus (Austria);

Nagy D., v., Professor of the königl. ungar. technischen Hochschule, Buda-Pesth, Müegyetem (Hungary);

Belelubsky N., Dr., Exc., Professor at the Imperial Russian Road-Engineering Institution, Member of the Engineering Council of the Ministry of Roads, St. Petersburg, 9 Zabalkansky (Russia);

Bogdanoff N., Civil Engineer, St. Petersburg, Wass. Ost., 4ème ligne 47, log. 5 (Russia);

Schilling T., Chief Chemist to the Moscow Share Co. for the Manufacture of Cement, Podolsk (Russia);

Proskuriakoff L., professeur de laboratoire de l'école des ingénieurs de Moscou, rue Bachmetieff (Russia);

Wikander A., Prof., Göteborg (Sweden);

Maclay W., W., Consulting Civil Engineer, 169, West Canfield Street, Detroit, Mich. (U. S. A.);

McKenna Ch. F., Chemist, 1553, Hudson Terminal Building, 50, Church Str., New York, N. Y. (U. S. A.).

On the basis of the experiments made in the Federal Testing Laboratory in Zurich and in the Municipal Testing Laboratory in Vienna, the chairman of the Committee laid before the Buda-Pesth (3rd) Congress of 1901 a report which concluded with the following proposal:

"As a preliminary indication of the strength development of Portland cement in tension and compression the six-day, hot-water test can be used.

"The briquettes composed of 1 part Portland cement by weight and 3 parts standard sand should be kept in a damp closet for 24 hours, after moulding, protected from currents of air and sunlight. The hot-water bath, after the introduction of the briquette should be gradually heated from 15 deg. C. to 100 deg. C. within

two hours, and be kept at this temperature. The water should be changed after three days and replaced by water of the same temperature.

"The employment of hot-water tests for the preliminary testing of the strength of Portland cement is not intended to dispense with the standard cold-water test."

The 3rd Congress has taken cognizance of this proposal, and has invited the Committee to continue their work in accordance therewith.

In October 1901, the Chairman after the Buda-Pesth Congress distributed a fourth circular among the Members of the Committee. In this circular the Members were desired to continue their studies on this question, and to give their views on the proposal above cited.

The circular further contained a reproduction of a communication subsequently handed in by Messrs. Belelubsky, Bogdanoff, Wassenko, and Konossewitsch in support of the hot water test, and an intimation, that the test-results given in the reports of the Buda-Pesth Congress bore reference only to hydraulic cements of constant volume and that the accelerated 6-day hot-water test for obtaining provisional information, referred to in the above proposal, had, in August 1901, been included in the Swiss Cement Standards.

Seeing that no expressions of opinion relating to this circular were sent in, and that the Council had, at their meeting of February 1907, decided that Committee N° 9 should be proceeded with, the Chairman in a fifth circular, dated April Ist., 1907, again invited the Members of the Committee to send him their proposals in regard to the question in such time that a report could be drawn up and presented to the Congress in Copenhagen in 1909.

In answer to these invitations, the following communications were sent in:

Mr. B. Feret, Chief of the Laboratory in Boulogne-sur-mer wrote on April 25th, 1907:

"In answer to your fifth circular, relating to the question of Committee N° 9, I beg to remind you that the observations made by several investigators tend to show that there is no proportionality between the degrees of strength attained by the test-

samples after they have laid for several days in hot water and after they have been kept for long periods in cold water respectively.

"I think it probable, therefore, that the accelerated test will not be able to yield results of any sufficient degree of interest."

Mr. L. Bienfait, Co-Chief of the Material-Testing Institution in Amsterdam, wrote on May 3rd., 1907:

"Although up till the time of the Buda-Pesth Conference an accelerated strength-testing process consisting in the keeping of the test-samples in hot water could perhaps be recommended, this seems, in view of the present conditions of the manufacture of cement, to be superfluous. After 6 days hardening in water of 15^0 to 18^0 C., indeed, by far the greater number of the Portland cements show such degrees of strength that a 6-day test of this kind may easily be made and regarded as final. Moreover, tests of only 6 days duration are often specified for Portland cement. If a searching test of an unfamiliar Portland cement be desired, the 6-day test will not be sufficient, and its extension so as to embrace a period of 1, 3, 6, or 12 months may be desirable. The troublesome and somewhat expensive hot-water test, in connection with which the samples have to be kept for 6×24 hours day and night in water of 100^0, is, in my opinion, a process, to which we should not go over."

Dr. W. Michaelis, Cement Technicist of Berlin, writes on April 22nd., 1908, as follows:

"I have always proposed and strongly recommended this accelerated hot-water test, after having long ago established the fact that in this way — not without exception, it is true — such an acceleration of the development of strength took place in the hydraulic hardening process, that the samples hardened in 7 days with the water at 100^0 C. were about equivalent to those hardened in 28 days with the water at 15^0 to 18^0 C.

"Now, since condemnations occasionally take place, the attainment of complete unanimity in regard to this accelerated process will probably not prove possible. I myself, however, give my vote for this test; for why shall we, on account of exceptions such as are everywhere encountered, refuse to help such a useful rule to recognition."

In April 1908 Mr. L. Deval, formerly Director of the Municipal Testing Establishment of Paris, submitted a detailed report supported

by numerous results of experiments, which appears in the form of a separate contribution to the report of the Committee, and in which the following results are reached:

"The strength of the hydraulic cements increases step by step in hot water for at least a year.

"On the other hand, the strength, although less in the beginning, increases more rapidly than in the other case, and continues to increase for a few months longer still.

"In regard to the value of the hot-water process as a rapid test, it cannot be admitted without risk of error, that this hot-water test yields the same result after 7 days as does the cold-water test after 28 days.

"The hot-water test does not, after 7 days, give clear indication as to what the ultimate strength of the cement will be. It gives information neither as to the maximum strength attainable in cold water, nor as to the strength-value after a test of three years — the period of test here ruling.

"Cements, in connection with which the hot-water rapid test has not shown a favourable result, or which are puffed up by the hot water, are not necessarily useless — at any rate not during a period of three years. The strength of such cements increases in cold water in like manner to that of the ones which show a favourable result under the hot-water test, and it may prove nearly the same as that of the latter.

"The hot-water test nevertheless has a tangible advantage; for it enables the presence of materials (which expand or shrink) to be detected.

"In our experiments the cubes were not acted upon by any external force. They were able, to gradually attain a degree of strength which enabled them, without perceptible alteration of form, to withstand the internal strains set up — during a period of at least three years — by the slow hydration of the expansive substances. The assertion is not justified, however, that the same thing happens during a long period of immersion, or under other less favourable circumstances, as for instance in sea water or under the influence of the atmospherie.

"To sum up, we may say, that although it does not appear possible from the strength point of view to found upon the hot-

water test a method for the rapid testing of cements, the hot-water treatment nevertheless yields valuable information, in enabling the presence of expansive ingredients to be detected."

In June 1908 Baurat A. Greil, Manager of the Municipal Testing Establishment for Hydraulic Cements in Vienna, sent in a report, which was supported by results of experiment, and which is likewise printed as a separate contribution towards the work of the Committee. Mr. Greil comes to the conclusion that on account of the unreliability of this method of testing, its adoption is not to be recommended.

Of the five gentlemen whose opinions are given, Mr. Michaelis is in favour of the hot-water test, while Messrs. Feret, Bienfait, Deval, and Greil are unable to recommend it.

Conclusions.

The numerous test-results given are in fact so contradictory, that the hot-water test appears too unreliable to admit of its being employed for rapid tests made to determine the strength of hydraulic cements.

Under the circumstances, then, it appears the right course, not to pursue the question of the applicability of the hot-water process for the acceleration of the testing of the strength of hydraulic cements, any further.

On the other hand the experiments of Mr. Deval have once more demonstrated how valuable this test may be for the giving of information as to the tendency of the cements to swell up and crack.

The question as to the attainment of constancy of volume of the cements is under consideration by Committee No. 32, which will no doubt take these suggestions into account.

Now while the proposal is made, that the question of the hot-water test as a rapid method for determining the strength of cements be allowed to drop, this does not mean that Committee N° 9, which was appointed to consider it shall be dissolved, but rather the suggestion is put before the individual members, that they pursue this important subject further, and it is thought that an elucidation of the chemical processes at work in the material may

yield tangible results such as may be applied so as to admit of a more rapid judgment of cements.

Any results of experience, that may be obtained, should then be communicated to the Chairman.

At the end of March, 1909, the foregoing report was sent to all the Members of the Committee in a 6th. circular in which these gentlemen were desired to give expression to their views with regard to it by the end of April. Answers favourable in every respect were received from the following gentlemen: — Mr. L. Bienfait, of Amsterdam, Mr. R. Feret, of Boulogne-sur-Mer, Mr. A. Greil, of Vienna, Mr. Dr. C. Heintzel, of Lünneburg, Mr. W. W. Maclay, of Detroit, Michigan, and Prof. D. P. Nagy, of Budapesth.

Dr. W. Michaelis, of Berlin, attributes the discrepancies (condemnations) in connection with the hot water test to the insufficient homogeneity of the original mixture, but admits that when rational advantage is taken of the improvement of the cements effected by means of finer grinding, a good idea of their performances may already be obtained in a much shorter time than formerly.

In view of this result of circular No. 6, the reporter believes himself justified in laying the above conclusions, as the expressed opinions of the Committee, before the 5th. Congress for final decision.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

X5

NOTE ON THE RAPID TESTING OF CEMENTS TREATED WITH HOT WATER.

By **M. E. Deval**, Paris.

Appendix to the report of Committee 9.

Translated from the French by A. R. Liddell, Charlottenburg.

When the hydraulic cements contain neither expansive ingredients (lime and magnesia in excess) nor salts that are decomposable by boiling water, hot water (at a temperature of 100° C.) gives their mortars at the beginning of their immersion greater strength than cold water.

On the other hand hot water produces a rapid hydration of the expansive ingredients, which shows itself, either in a diminution of the strength, or in swellings and cracks.

According to the circumstances, then, hot water may accelerate or retard the hardening of the mortar.

We have endeavoured, at different stages in the hardening process, to compare the strengths of the hydraulic cements (neat and sand briquettes) immersed in hot water (of 80° to 100° C), with those attained by the same materials after the same times of immersion in cold water (of 15° to 18° C.).

We have then investigated the question, whether hot water, which at the outset gives greater strength to the mortars, could be used for the rapid testing of cements, and would give any indication of their ultimate strengths.

Our briquettes in figure-of-8 form have a sectional area of 5 square centimetres. The neat briquettes were prepared

with 25 per cent of water, and the sand briquettes with a proportion of water equal to 11 per cent of the combined weight of cement and sand. These latter mortars had the consistency of moist earth and were stamped into the moulds.

The briquettes were kept sheltered from draughts and from the rays of the sun for 24 hours in the laboratory cellars before being immersed either in hot or in cold water.

The strength increases with the time of immersion in hot water.

Our tests were made on Portland cement, slag cement, and quickly-setting Vassy cement.

The briquettes were broken by tensile strain after periods of 2 days, 7 days, 28 days, 3 months, 6 months, 9 months, and one year respectively.

In connection with the Portland cements, we have found that the strength of the neat briquettes under the heat treatment, which is at first greater than that under the cold one, gradually rises in spite of some irregularities in the results, but increases less rapidly than the strength in cold water, which almost always exceeds the other at the end of a year. The strength of the sand briquettes (1 part cement to 3 parts by weight of standard sand) in hot water keeps its place, except in a few cases, above that in cold water at all stages of the tensile tests.

With very aluminous cements, such as those made of slag, which contain from 15 to 16 per cent of alumina and therefore a large proportion of aluminate of lime, the general course of the hardening process is the same. It not infrequently happens, however, that the strength of the neat briquettes in hot water at the end of two or even of seven days remains less than that in cold water by reason of the dehydration of the aluminate of lime by the water of 100° C. The strength of the sand briquettes under heat is in general superior to that under cold at all stages of the tensile tests.

In regard to the quickly-setting cements, such as the Vassy cements, the neat briquettes are found to give results similar to those with Portland cements; but with the sand briquettes (2 parts by weight of cement to 5 of sand) the similarity is less complete.

In short, the strengths of the Portland, slag, and Vassy cements (whether in the forms of neat or sand briquettes)

continues to increase in hot water for a year, which was the limit of duration of our tests.

In view of the circumstances that hot water in general accelerates the setting of mortars and increases their strengths, at least at the beginning of their immersion, the attempt has been made to found a method of rapid testing of cements on the hot-water process.

Some experimenters have thought that the strength in hot water after a 7-days immersion would be sensibly the same as that in cold water after a 28-days immersion.

Our experiments relating to this point have only been extended to neat briquettes of Portland cement.

Amongst 109 tests, we only found 14 the results of which differed from one another by less than 3 per cent of the strength-value under heat and 33 in which the difference did not exceed 19 per cent.

The differences are sometimes positive and sometimes negative; they range up to 63 per cent.

It will be apparent, then, that, even though a variation of 10 per cent were regarded as negligible, an agreement of results is established only for 47 tests out of 109, The experimeter, then, may be said to run the risk of deluding himself in 57 cases out of 100, should he take, as the probable strength of cement in cold water after a 28-days immersion, that which he would have found by a rapid test in hot water.

Can the tensile tests on neat briquettes after 2 and 7 days immersion in hot water respectively, nevertheless, give indication of the ultimate strengths of these cements and of their mortars?

We do not think so; for we have not found any proportionality between the strengths of the cements in hot water after seven days and those which they develop in cold water at any period of their immersion ranging up to three years.

We cannot here set forth all the results of our numerous tests; we shall only give some of them in the following table in order to show that equal strengths obtained under 7-day heat-tests may correspond with strengths under 3-year cold water tests that differ widely from one another and vice versa. It may

indeed be observed that the strength after 3 years may even be less than that in the 7-day test with hot water.

	In kilogrammes													
Strengths in hot water after 7 days immersion	53·60	50·70	42·50	22·00	40·00	34·25	42·75	39·00	29 50	38·00	53·75	44·00	54·75	51·50
Maximum strengths after from 2 to 3 days in cold water	66·75	71·00	65·25	58·75	58·25	59·00	50·50	53·50	56·00	61·65	67 25	68·00	63 25	58·70
Strengths in cold water after 3 years' immersion	54·50	58·50	65·25	58·75	58·25	59·00	41·25	35·75	54·00	57·25	60·25	61·75	59.25	55·25

Should we à priori reject the cements for which the rapid test under heat has shown the presence of expansive ingredients?

We have observed above that the cements that are devoid of expansive ingredients, will, when first immersed, show greater strengths in hot than in cold water. Such is the behaviour of cements reputed to be of good quality. Cold water tests which we have made on cements of this kind, immersed for periods of three years, have shown us that the curve of results given by breaking at different periods varying from two days to three years, shows ups and downs and a maximum which does not necessarily correspond with the result of the last test. This maximum, which shows itself at different periods, according to the cement in question, does not occur simultaneously in the tests on the neat briquettes and on those of the corresponding sand briquettes.

The cements which in hot water show departures from the general rule which we have just enunciated in our experiments, behaved in three different ways:

1. The strength in hot water has been less than that in cold water, it may be after two days or after seven days.

2. A fall is shown in the strength under the hot test on the seventh day.

3. The hot water has developed cracks and swellings.

These anomalies are attributed to the hydration of the expansive ingredients; the uncombined lime and magnesia, which have been overburnt during the manufacture of the cement, are

then hydrated only very slowly, while hot water facilitates their hydration. This may begin at the beginning of the experiment, as in the first case, or it may not show itself till after an immersion of several days, as in the second case.

Side by side with the rapid tests with hot water, we have with the same cements undertaken tests of long duration in cold water in order to ascertain whether the cements showing the anomalies to which we have just referred, show certain irregularities in the cold-water test of such a kind as to cause them to be looked upon as defective.

We have found, on the contrary, that the setting and hardening in cold water are not influenced in the same way as in the case of the cements which in hot water follow the ordinary rule. The curve of strength shows ups and downs, and passes through a maximum which is not always at the point corresponding with the last test.

The following table gives the limits between which, according to our experience, the maximum strengths and the strength after three years of immersion have varied for the cements which have followed the general rule and for those which have shown the different anomalies referred to above.

Results of the hot tests with 2 and 7 days immersions	Strength maxima in cold water kgs.	Strength after 3 years immersion in cold water	
		pure cakes kgs.	mortar $^1/_3$ kgs.
The strength at the hot test is superior to that at the cold test . . .	from 40·25 to 71·00	from 32·25 to 68·25	from 16·50 to 40·25
The strength at the hot test is inferior to that at the cold test . . .	„ 52·50 „ 68·25	„ 42·25 „ 57·25	„ 20·00 „ 43·25
A fall occurs in the strength at the hot test on the 7th day . . .	„ 45·00 „ 62·50	„ 39·00 „ 62·50	„ 19·75 „ 40·50
The hot water has caused swellings or cracks . .	„ 45·25 „ 58·00	„ 40·50 „ 58·00	„ 22·75 „ 35·00

The cements of the first line are those which are reputed to be of good quality. It will be observed, that the cements of the

2nd, 3rd and 4th lines, which have shown anomalies in hot water, have in cold water acquired strengths that fall within the limits shown by those of good quality.

From the point of view of the strength to which they can attain, whether in the form of neat or sand briquettes, the cements whose briquettes develop swellings in hot water are not, therefore, necessarily bad. The hot water has merely enabled us to recognize the presence of an element which, though perhaps a source of future danger, does not show itself during the three years that our experiments lasted. It is, further, a matter of common knowledge, that a short exposure of a cement to moist air often suffices to prevent it from swelling further in hot water.

Conclusions.

The conclusions which the experiments, the results of which we have briefly touched upon in the foregoing, have led us to form may be formulated as follows:

The strength of hydraulic cements increases progressively in hot water for at least a year; but the strength in cold water, at first inferior to the first-mentioned, increases more rapidly and takes the lead after a few months.

From the point of view of rapid testing, it cannot be said that strength under the hot test at the end of 7 days is always equal to that in cold water at the end of 28 days.

The hot water test does not, after a 7 days immersion, enable the ultimate strength of the cement to be predicted. It gives no certain information, either as to the maximum attainable by the strength under the cold treatment, or as to the value that the latter will show at the end of the three years to which our tests extend.

The cements for which the rapid hot-test has been unfavourable, or which hot water has caused to swell, are not necessarily dangerous, at any rate for a period of three years. Their strength increases in cold water in a manner analogous to that of the cements the hot-tests of which have been satisfactory, and this strength may become nearly equal to that of the latter. In our experimenting-troughs, however, where the briquettes have been submitted to no external strain, they have been able gradually to acquire sufficient strength to withstand the internal strains set up

by the slow hydration of the expansive ingredients without visible deformation. It cannot, however, be asserted that the same will be the case for a longer period of immersion than three years, or under other less favourable conditions, as for instance near the sea or under the influence of atmospheric agents.

To sum up, we may say, that although it does not appear possible from the strength point of view to found upon the hot-water test a method for the rapid testing of cements, the hot-water treatment nevertheless yields valuable information in enabling the presence of expansive ingredients to be detected.

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X 6

ON RAPID METHODS FOR DETERMINING THE STRENGTH OF HYDRAULIC CEMENTS.

By **Alfred Greil,** Vienna.

(Appendix to the Committee Report 9.)

Translated by A. R. Liddell.

In the years 1901, 1902, 1903, and 1907 a series of 6-day hot-bath tests were made in the Municipal Testing Laboratory for Hydraulic Cem ents in Vienna, so as to afford a comparison with the 28-day cold water tests with Portland and slag cements. The results thereby obtained are put together in the tables here annexed.

From this long series of experiments, which in the first three years were directed towards the determination of the compressive strengths and in 1907 towards that of the tensile and compressive strengths, an agreement between the results was not, it will be seen, obtained, but these showed considerable fluctuations, the hot-bath test sometimes giving the better and sometimes the worse results in the individual cases.

In the case of the Portland cements the differences are not so considerable as in that of the slag cements, with which, in the hot-bath test, considerably poorer results were almost without exception obtained.

For slag cements the shortened hot-bath test is altogether unsuitable; for in the case of 29 comparative tests, the 28-day tests in 27 instances gave higher and often far higher results than the hot-bath tests.

With Portland cements the hot-bath test gave the better results in 23 cases out of 87, while the cold-bath test gave the

better results in 64 cases. Only in 16 cases did the differences in the compression-tests vary so little, that the question of sufficiency of agreement could be considered at all.

It remains to be mentioned, that all the samples tested completely withstood the drying and boiling tests.

In view of the tests made, the conclusion is warranted that the introduction of this new and rather circumstantial method of testing is undesirable.

Portland Cements with Sand 1 : 3.

In			
Hot		Cold	
Water after			
6		28	
Days			
Tension	Compression	Tension	Compression
1901.			
	191·20	21·58	207·—
	221·—	23·15	229·50
	138·25	19·93	184·—
	257·50	25·15	223·50
	249·50	25·78	240·—
	274·—	26·78	251·50
	120·50	21·80	206·—
	243·75	23·30	218·—
	117·25	21·63	208·—
	187·50	27·78	226·50
	210·75	25·78	251·50
	242·75	31·93	321·—
	202·75	23·75	220·—
	209·25	20·98	221·25
	247 25	18·75	191·25

In			
Hot		Cold	
Water after			
6		28	
Days			
Tension	Compression	Tension	Compression
	235·—	23·80	215·50
	222·50	23·73	219·50
	308·75	23·20	209·50
	232·50	23·48	208·—
	244·75	22·98	205·75
1902.			
	275·50	24·18	241·—
	201·50	28·85	276·50
	214·75	26·—	220·—
	226·25	22·40	214·25
	184·—	28·90	274·75
	176·25	22·13	218·—
	226·75	22·05	206·25
	255·—	27·78	270·25
	212·—	24·83	232·50
	203·50	25·58	233·—

In			
Hot		Cold	
Water after			
6		28	
Days			
Tension	Compression	Tension	Compression
	261·—	27·68	267·25
	227·—	29·—	275·25
	220·50	27·60	272 25
	215·50	29·—	272·75
	186·75	31·05	291·50
	256·75	27·70	274·—
	301·75	30·05	313·—
	283·50	33·18	309·—
	266·25	29·65	309·—
	248·—	29·98	304·25
1903.			
	158·75	24·18	215·50
	216·75	32·03	301·50
	284·—	34·10	307·—
	273·25	24·85	226·25

Portland Cements with Sand 1 : 3.

In				In				In			
Hot		Cold		Hot		Cold		Hot		Cold	
Water after				Water after				Water after			
6		28		6		28		6		28	
Days				Days				Days			
Tension	Compression	Tension	Compression	Tension	Compression	Tension	Compression	Tension	Compression	Tension	Compression
1907.				22·53	246·50	30·78	267·—	22·95	224.—	26·45	254·—
				20·85	188 50	29·08	239·75	18·83	238·—	27·08	247·75
17·25	179·—	23·85	223·—	23·38	274·—	30·63	279·—	10·75	103·50	23·05	229·—
21·35	218·25	22·95	221·25	24·33	243·25	28·—	285·75	17·23	192·—	23·45	206·50
25·98	246·50	27·93	235·—	22·—	238·75	27·35	266·25	8·53	80·75	21·35	218·25
18 65	282·75	24·75	219·—	25·43	212·75	27·50	303·25	21·08	219·50	25·—	255·75
27·50	271·—	28 65	261·50	23·93	220·25	30·90	302·—	14·88	197·75	24·80	218·50
26·05	272·25	29·65	279·25	25·28	307·40	27·85	275·50	20·00	234·—	27·78	231·25
25·53	246·—	28·63	233·—	26·70	274·—	26·65	239·—	21·75	204·25	26·07	241·75
22·93	253·75	27·—	234·75	25·78	247·—	25·40	255·75	26·50	213·—	29·32	267·25
24·38	259·50	26·45	229·25	24·33	257·—	26·73	258·25	18·18	242·—	28·33	255·25
24·40	184·—	27·58	234·75	22·10	216·—	27·43	269·25	17·33	149·75	25·25	254·50
25·33	251·75	26·58	266·—	23·63	157·25	27·08	256·—	21·20	174·25	25·55	269·—
24·88	255·50	28·50	280·75	25·33	253·25	27·28	253·—	15·95	147·25	30·63	298·75
26·80	259·—	28·32	276·25	23·60	243·75	26·48	241·25	17.13	158·50	28·40	281·75

Slag Cements with Sand 1 : 3.

In				In			
Hot		Cold		Hot		Cold	
Water after				Water after			
6		28		6		28	
Days				Days			
Tension	Compression	Tension	Compression	Tension	Compression	Tension	Compression
			1901.				
	216·50	27·90	254·25				
	224·—	29·48	267·—				
	176·25	26·88	272·25				
	181·75	30·50	296·25				
			1902.				
	183·—	30·53	240·25		132·50	23·73	202 75
	131·25	29·70	232·75		153·75	22·55	213·—
	148·—	29·75	263·75		156·—	26·75	224·75
	134·50	28·55	259·50		121·25	25·53	218·75
	163·75	30·13	269·50		127·25	26·88	220·—
	161·50	28·45	267·—				
	161·25	29·15	232·25				
	158·75	29·10	253·—				
	159·75	28·25	250·—				
			1907.				
24·38	169·75	28·43	230·75	32·13	187·75	28·53	248·25
22·85	166.75	28·45	238·—	26·75	256·25	27·30	244·75
24·63	146·25	27·10	266·75	25·13	170·50	30·33	252·75
23·28	148·75	28·35	229·75	26·40	168·50	31·18	283·25
24·18	154·75	26·55	219·75	24·43	126·—	31·03	241·75
24·53	189·50	26·60	226·—	27·63	178·50	28·33	244·25
24 33	170·50	27·80	226·—	26·13	177·75	30·08	271·50
22·18	154·50	29·—	229·25	25·63	180·—	27·60	243·25
21·53	135·50	27·28	222·50	22·75	171·25	29.53	254·25
21·88	135·75	28·33	222·25	23·30	156.75	28·55	245·25
18·53	150·—	24·23	217·25	23·70	168·75	30·43	255·25
27·60	283·25	28·—	234 25	20·50	169·—	29·55	257·—
18·45	149·50	28·37	221·75	22·25	161·50	30·53	245·75
19·18	140·75	26·45	217·50	21·05	160·50	29 33	260·—
18·65	137·50	26·48	221·50	21·53	176·50	29 03	256·—
19·28	143·25	27·75	238·50	20·48	167·75	29 43	253 —

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XVII 1

ON THE CORROSION OF IRON IN WATER AND AQUEOUS SOLUTIONS.

By Prof. **E. Heyn** and Prof. **O. Bauer**, Gr.-Lichterfelde.

(Translated from the German original by G. Lemmey.)

The authors gave in numbers 1 and 2 of the "Mitteilungen des Materialprüfungsamtes, 1908", a paper under the above title, from which some of the most important points have been taken and collected in the present report. For further information, therefore, reference should be made to the paper in question. The work it deals with was carried out from 1900 to 1907 in the Royal Testing Laboratory, Groß-Lichterfelde, and is still being proceeded with.

The degree of corrosion of iron, as it occurs under various cicumstances in liquids, is estimated by recording the loss in weight of small iron plates, after an exposure lasting generally over a period of twenty-two days, and the data given apply to the reaction as taking place at the ordinary temperature of the room, when no mention to the contrary is made.

A. Influence of oxygen and carbon dioxide on the corrosion of iron in water and dilute solutions.

1. The two essential factors which determine the corrosion of iron in water and in aqueous solutions are the presence of the water in its liquid state and of oxygen. The presence at the same time of carbon dioxide is not essential. The very important action of oxygen was alluded to by M. Traube in 1885. Spennrath proved that the presence of

oxygen was a fundamental condition and that the presence of carbon dioxide was not necessary for rust formation. The authors of the present report have by a series of researches also proved that carbon dioxide is a superfluous element in the matter and have arrived at similar results to those recently found by Dunstan.

The tests described in the above mentioned paper by the authors show that air containing about 15 % of carbon dioxide, has an action upon iron in contact with distilled water only about double that of air which is free from carbon dioxide, other conditions being the same. This proves that the small proportions of carbon dioxide contained in the atmosphere can have no influence to speak of upon corrosion.

2. By excluding oxygen, the attack of iron in water and aqueous solutions can be prevented in so far as the liquids considered have not the character of acids. By checking the access of oxygen to the liquid rust formation is also checked to a corresponding degree.

The attempt to prevent the oxygen in the atmosphere from having access to the water, by covering the latter with an oil film, the object being to preserve the iron surrounded by water from corrosion, fails because oil absorbs oxygen much more readily than does water and passes on the oxygen to the water beneath it.

On the other hand, by suspending inside the water small bags filled with powdered charcoal, it is possible, in certain circumstances, to reduce corrosion to one fifth its normal amount, the charcoal absorbing the dissolved oxygen from the water. This method may perhaps prove capable of practical applications.

3. A pure solution of carbon dioxide in water, cannot, if oxygen be excluded from it, give rise to rusting; it has however, as all acid solutions, a solvent action accompanied by an emission of hydrogen. Rusting can only set in when at the same time oxygen is present in the solution. The reactions, adopted by the advocates of the „carbon-dioxyde theory of rusting", viz:

a) $Fe + CO_2 + H_2O = FeCO_3 + H_2$

b) $2FeCO_3 + 3H_2O + O = Fe_2(OH)_6 + 2CO_2$

may therefore very well occur, but are not indispensable with the formation of rust, for the latter can set in quite independently of the presence of carbon dioxide. If there be no oxygen present then

reaction (a) can proceed only up to a certain limit, which is determined by the degree of solubility of the iron carbonate in water containing a carbonic acid.

When, therefore, the mass of water acting on the iron is limited in volume and kept saturated with carbon dioxide, corrosion of the iron consequent upon the passage of pure carbon dioxide through the water, may be less in extent than is produced by passing through the water a mixture of air and carbon dioxide, or of air free from this latter gas.

Conditions of course are different when fresh masses of water, each saturated with carbon dioxide are allowed to play continuously upon the iron. In such a case the solvent action reaches no limit but can continue indefinitely and the action of water containing carbonic acid, air being excluded, may thus be greater than that of water containing air free from carbon dioxide.

4. Let us denote by "c" the number of gramme molecules of oxygen in one litre solution in the immediate vicinity of the iron plate at the end of the time "z"; and by c_0 the number of gramme molecules of oxygen corresponding to the complete saturation of the liquid. Then the greater "c" becomes in the vicinity of the iron the faster does the formation of rust proceed. The rapidity of corrosion and consequently the consumption of oxygen in the unit of time is therefore proportional to "c". The oxygen supply is taken in at the upper surface of the liquid and reaches the iron by diffusion. The rapidity with which the supply is renewed can with sufficient accuracy be taken as proportional to the difference in oxygen concentration $c_0 - c$. Therefore, the change that takes place in oxygen concentration in the unit of time and in the vicinity of the iron is

$$\text{a)}\quad \frac{dc}{dz} = -kc + k_1 (c_0 - c)$$

where k and k_1 represent coefficients independent of c.

After a certain time z′ equilibrium will be established between the consumption of oxygen k c and the supply of oxygen $k_1 (c_0 - c)$; then the change in concentration $\frac{dc}{dz} = 0$. Hence, after this time we have

$$\text{b)}\quad k c' = k_1 (c_0 - c')$$

where c′ represents the oxygen concentration after equilibrium has been reached in the portion of the fluid in contact with the small mass of iron. If "v" be the loss in weight of the latter through rusting during the time z, the speed at which rusting is being effected is then given by the relation

$$\text{c)}\quad \frac{d\,v}{d\,z} = k\,c', \text{ and also}$$

$$\text{d)}\quad \frac{d\,v}{d\,z} = k_1\,(c_0 - c') = \frac{k\,k_1\,c_0}{k + k_1}.$$

The value of k depends on the area of the iron exposed; this plays an important part in the reaction. Hence direct comparison is only possible between experiments in which equal surfaces of iron have been exposed. From the above equations the following deductions may be drawn, all of which have been confirmed by actual experiment:

α. For similar concentration differences $c_0 - c_1$ the value k_1 is substantially dependent upon the distance between the layers of liquid in which the concentration has its maximum value c_0 and those layers in immediate contact with the iron, where the concentration is c′. If the degree of concentration c_0 prevails solely at the surface of the liquid in contact with the atmosphere, then the distance between the iron and the upper surface of the liquid has a predominaut influence on the value k_1. The greater this distance, the smaller does k_1 become and the smaller also the rate at which corrosion proceeds. The distance is least when the iron is only partially immersed in the liquid, in which case air has direct access to the point of contact between the iron and the upper surface of the liquid. At such a point $c' = c_0$, whilst at greater depths from the upper surface of the liquid, c′ gradually decreases. The attack on the iron is consequently most severe at the upper surface of the liquid. Here a spongy mass of rust is speedily formed and this beeing more permeable than water to the surrounding air, a high concentration of oxygen takes place through the spongy oxide which reaches the metal to some depth beneath the liquid surface, giving rise to increased corrosion.

The highest concentration of oxygen does not however necessarily occur at the upper surface of the liquid. In certain instances, air bubbles which form in certain parts of the liquid have also the same effect[1])

β. The area of the upper surface of the liquid through which the atmospheric air is diffused down to the iron, affects the value k_1. The greater this is, the faster does rust-formation take place, other conditions being the same. The formation of concentration currents also depends upon the extent of this area and the distribution of the oxygen concentration c in the liquid is greatly influenced by such currents, leading to irregularities in the attack of the iron.

γ. If the oxygen concentration $c' = c_0$ be maintained in the neighbourhood of the iron by means of a constant current of fresh air finely divided, then we have $dv : dz = kc_0$ and the rate of corrosion attains its highest value. This makes evident the difference which exists between corrosion tests in which air has passed through the water to the iron, and those where air is alone allowed to act direct on the surface of the metal, either as a current or quiescently. In the first case the rate of corrosion is, for instance, twice as great as in the two latter.

δ. If c_0 be increased, by increasing the partial pressure of the oxygen in the atmosphere in contact with the liquid, a correspondingly increased rate of corrosion is obtained according to equation (d). An increase in the partial pressure will occur when the pressure of the air in contact with the liquid is raised. Then c_0 increases proportionally with the pressure. But the partial pressure can also be increased when a mixture richer in oxygen than the air is brought in contact with the liquid.

Seeing that the solubilities of nitrogen and of oxygen in water are in the ratio 1 : 1·9, by heating a liquid saturated with air, a gas mixture is obtained richer in oxygen than ordinary air. Should this gas mixture collect in bubbles on the surface of the iron placed in water, such, for example, as on parts of steam boilers under pressure, there are then two causes for an increase in the rate of corrosion; first, the increased partial pressure of the oxygen by reason of the greater oxygen proportion in the gas of

[1]) E. Heyn: "Researches on the corrosion of iron in water". Mitt. Kgl. Techn. Versuchsanstalten, 1900, pag. 38.

the bubbles, and, in the second place, the increased partial pressure owing to the greater total pressure of the gas mixture.

If the pressure on water saturated with air be suddenly decreased, then an oxygen-nitrogen mixture, corresponding to the difference in the two pressures, is given off in the shape of bubbles, and these are occasionally so numerous and finely divided that the water takes a milky appearance. If water in this state comes into contact with iron, it induces corrosion as great as would be obtained by passing a mixture rich in oxygen through the water.

ε. The renewal of the liquid has a great influence on the rapidity of corrosion. Should, for instance, the water contained in a vessel and with which iron is in contact, be constantly renewed by fresh water saturated with air (by a constant current, for example, flowing in and out the vessel), then c' is always equal to c_0 as in case γ; and the rate of corrosion $dv : dz$ then reaches its highest figure. But the rate of corrosion is also increased when renewal does not take place so rapidly that $c' = c_0$.

ζ. The proportion of the exposed surface of the iron to the volume of the liquid has also a marked influence upon the rate of corrosion. If a number of iron plates be placed one over the other in a vessel containing the liquid, the oxygen concentration c' corresponding to the equilibrium state, will be different at the various distances from the upper surface of the liquid, reaching the limit o at a sufficiently great distance. If a number of plates of iron of different qualities were thus exposed to the action of the liquid, it would be a great mistake to attempt to compare one with the other as to their resistance to corrosion. A mistake of the same nature is made when the current of liquid is supplied at some particular point of the vessel in which are placed, for comparison, iron specimens of various qualities. A high concentration of oxygen prevails at the point at which the liquid highly saturated with air is supplied, this concentration decreases with the distance from the point of supply. The specimens at a distance from the inlet will therefore be under conditions quite different from those which obtain at the point of supply. A comparison of their relative corrosions is therefore out of the question.

5. A number of tests have been made which show that the inner surfaces of the bell plates of a gas holder which dip into the water-seal, corrode when they are not covered

with an efficient protective coating. This observation decides a question of great practical importance. The experiments showed that lighting gas reduced the corroding effect, but that it did not actually prevent it. Corrosion takes place in this case because the oxygen from the atmosphere is able to diffuse to the iron through the water-seal.

B. Influence of contact between iron and other metals upon the rate of corrosion in water and aqueous solutions.

The following law generally applies:

a) When iron is in contact with one of the less noble metals[1]) in the series of contact potential differences and both metals are placed in aqueous solutions producing corrosion, the corrosion of the iron decreases while that of the other metal is accelerated, and

b) When the iron is in contact with a nobler metal[2]) in the same series, in similar conditions, the corrosion of the iron is largely increased.

The classification of metals by these contact potential differences is not a hard and fast one, but varies with the liquid in which the metals are plunged, so that the position of a metal in the list may change with the liquid.

It should be added at this point that for the production of effects under a) and b) it is not necessary that there should be sufficient potential difference between the two metals placed in the liquid, to lead to a visible decomposition of the water, since the effect is observable at even a very low potential difference, though it naturally increases as this rises. The above laws are dealt with in a masterly manner by Diegel in his most valuable work „The preservation in sea water of the more common copper alloys“[3]). In this work can also be found most comprehensive data and illustrative quotations of the highest technical value.

1. The contact of iron with copper increases corrosion on an average by 25 % in the case of town supply water, the corresponding figure being 47 % in artificially prepared sea water. By

[1]) More electropositive, as zinc for instance.

[2]) More electronegative as copper.

[3]) „Marine-Rundschau“ IX, 1898, 11th issue, p. 1485.

special experiments, il was proved that the decomposition of water plays no part in the reaction. The effect of the copper is that it causes the oxygen in the water to act more energetically upon the iron electrode than when there is no copper in contact with the iron. Where there is no oxygen in solution, the iron, even when in contact with copper, is not attacked.

2. Iron in contact with nickel: The tests showed that iron in contact with nickel, both being placed in water, corroded about 15% more than when not in contact with the nickel.

3. Steel in contact with cast-iron under water: The tests showed that cast-iron does protect steels. Corrosion of the latter is decreased by 50% when air is merely allowed free access to the water surface, and by 28% when the air is passed through the water. At higher temperatures, at 60 degr. Ct. (140 degr. F.), for example, similar effects were observed, there being a decrease of about 16% in the corrosion of the steel.

4. Contacts between iron specimens cut from the same bar but differently treated: It was found that two specimens taken from the same iron, but worked-up differently (by rolling, forging, heating etc.), and placed in water, in contact with each other[1]), generally show an electric potential difference, and this would tend to prove that they have an influence one upon the other in the matter of corrosion; the iron which happens to be in a less noble state is attacked more energetically and protects the more noble one. Such influences are commonly undervalued by technical men.

As an illustration of this, we may mention the result of a research made with the object of finding out the cause of the deep corrosion of the steel of a steam boiler at the points where the Galloway tubes were welded to the flue. This showed that at those parts where hammering of the weld down to red heat was not possible, the steel had become overheated[2]), while at greater distances from the welds, the steel showed no indication of overheating. Further special tests indicated that steel which is not over-

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[1]) It should be remarked that in an iron sulphate solution, this difference does not of a necessity occur.

[2]) For more particulars on this point see: E. Heyn, „Diseases of iron and copper“: „Z. Verein. D. Ing.“ vol. 46. 1902.

heated occupies a less noble position in the series of contact potential differences than that which is overheated, and that the potential difference between the two may reach a considerable value. Consequently, when overheated and non-overheated steel, of the same chemical composition are in contact with each other in water, the non-overheated iron will be more strongly attacked than if there was no such contact. Tests showed that the ratio of attack of the overheated steel to that of the non-overheated, the two being in contact in distilled water, was from 1 : 1·25 to 1 : 1·5.

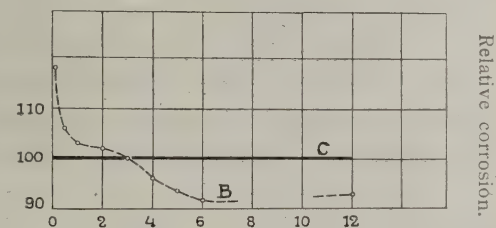
C. Comparison of several classes of iron with regard to corrosion in water.

Although it may be stated in the following that one kind of iron rusts more than another, this does not apply to the entire class of the iron from which the test specimens were taken, but only to the material tested, in particular cases and only to the particular conditions which governed the test.

a) Influence of manganese and phosphorus in cast-iron.

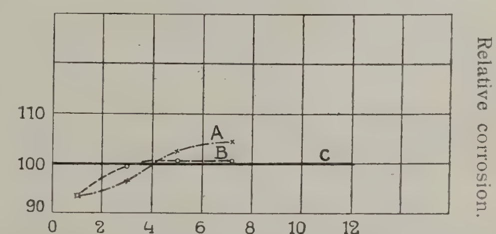
The result of a series of researches with cast-iron was that the influence of the percentage of manganese and phosphorus within the limits of 0·46 to 3·08 Mn and 0·072 to 3·38 P based upon tests in water lasting over twenty-two days, is negligible as compared with the influences discussed in the foregoing.

Fig. 1.



Time in months.
C, steel = 100. B, Wrought iron.

Fig. 2.



Time in months.
C, steel = 100. A, Cast-iron. B Wrought iron.

b) Comparison between soft steel, wrought and cast-irons.

The experiments showed, so far as twenty-two day tests go, that it is questionable whether there is any greater attack on cast-iron than on the two kinds of malleable iron tried; at all events, the difference, if any, is much less than is generally admitted. It falls into the background, therefore, when compared with the variations brought about by the other influences, already alluded to.

The results of researches lasting over long periods are illustrated in the diagrams figs. 1 and 2. In one experiment, fig. 1, the wrought iron rusted at first more rapidly than the steel; later on, however, the conditions were reversed and after a twelvemonth the rust formation on the steel stood, to that on the wrought iron, as 100 to 93. The result of the second test was again different, as shown in fig. 2. In this the wrought iron first rusted more slowly, the rate increasing somewhat after seven months had elapsed, after which period the ratio: steel to wrought iron, was 100 to 100.5. The ratios require further study, but the experiments however, show that the class of the iron has but a limited influence. Fig. 2 also shows the curve for cast-iron. The small cast-iron plates were slightly thicker than those of the wrought iron and of the steel. The curve shows the corrosion compared with that of the steel after correction for the greater surface exposed. The statement already made holds here also and in these corrosion experiments the cast iron behaved in practically the same way as the two kinds of malleable iron.

Seeing that in the literature dealing with the subject the assertion is frequently made that the solubility of materials in sulphuric acid furnishes a fair criterion of their susceptibility, to rusting we state below the figures observed for the classes of iron above referred to: The loss in weight in sulphuric acid (1 % solution) was in the following ratios:

Soft steel : wrought iron : cast iron = 1 : 2 : 100.

Further, the relative facility of corrosion in water kept constantly saturated with carbonic acid was in the ratios:

Soft steel : wrought iron : cast-iron = 1 : 1·31 : 4·3.

From this it is seen that the behaviour of these metals in regard to these acids forms no measure of their susceptibility to rusting.

D. Comparative experiments on the action of various liquids in furthering the corrosion of iron at ordinary temperatures.

In all the experiments, the installation was so arranged that the supply of oxygen was not effected by passing air through the liquid, but by diffusion through the upper surface of the solution. The area of the upper surface of the liquid and the distance of iron specimens from the surface were maintained the same in all the experiments; the exposed area of all the iron specimens was of course also the same in every case. The loss in weight of the small iron plates after a period of twenty-two days was taken as a measure of the corrosive effect. Detailed information is given in the work referred to at the commencement of the present report. In this the results of the experiments are stated in tabular form and by diagrams. The reproductions herewith (figs. 3 to 6) illustrate several of the principal types of the curves. The abcissae are proportional to the logarithms ξ, of the gramme equivalents c (concentration) of the dissolved substance contained in one litre of the solution. The ordinates indicate the loss in weight v of the small iron plates, in grammes, observed after a period of twenty-two days. The curves may, for shortness, be called ξv curves. Experiments were carried out with thirty-eight different electrolytic solutions.

The course of the ξv curves for each individual electrolyte is very generally similar. Highly dilute solutions have mostly a somewhat weaker effect than has distilled water[1]), and the curve therefore first falls, rising afterwards. At some particular concentration c_h the curve showing the rate of attack on the metal reaches a maximum (fig. 4) and then on a further increase in the concentration, the attack gradually decreases again.

Concentration c_h is styled the "critical concentration" and the solution to which it applies is denominated "critical solution".

Such peaks of maximum corrosion do not however occur in the case of the following solutions, with which there is a deviation from the above rule: chromic acid, potassium bichromate,

[1]) Concentration $c = 10^{-6}$ is arbitrarily given to distilled water, therefore abcissae $\xi = -6$.

Fig. 3

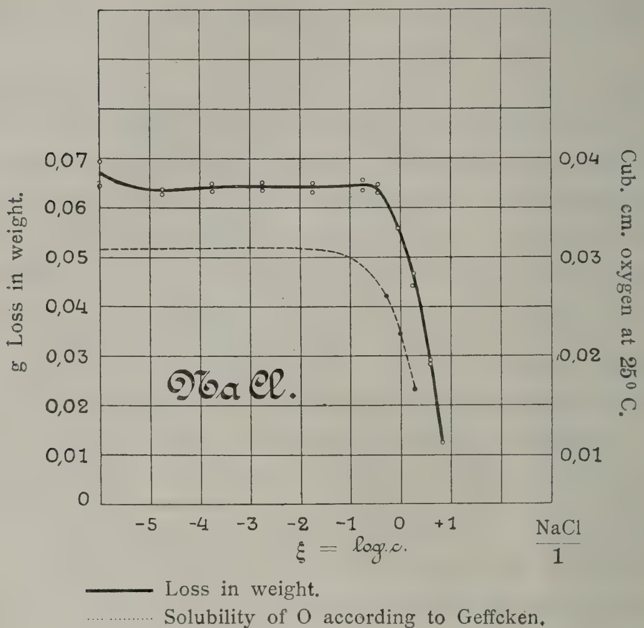

0,07
0,06
0,05
0,04
0,03
0,02
0,01
0
g Loss in weight.
0,04
0,03
0,02
0,01
Cub. cm. oxygen at 25° C.
NaCl.
-5 -4 -3 -2 -1 0 +1
ξ = log.c.
NaCl
1
Loss in weight.
Solubility of O according to Geffcken.

Fig. 4.

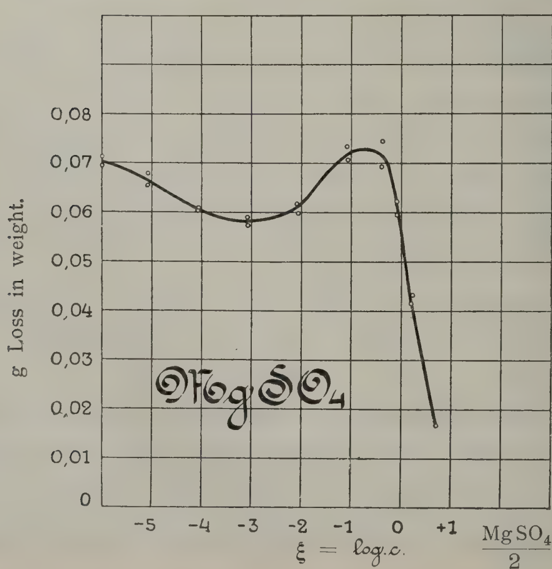

0,08
0,07
0,06
0,05
0,04
0,03
0,02
0,01
0
g Loss in weight.
MgSO4
-5 -4 -3 -2 -1 0 +1
ξ = log.c.
MgSO4
2

Fig. 5.

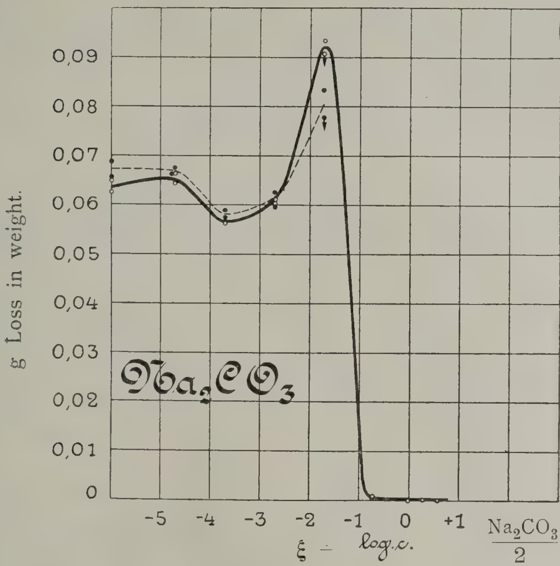
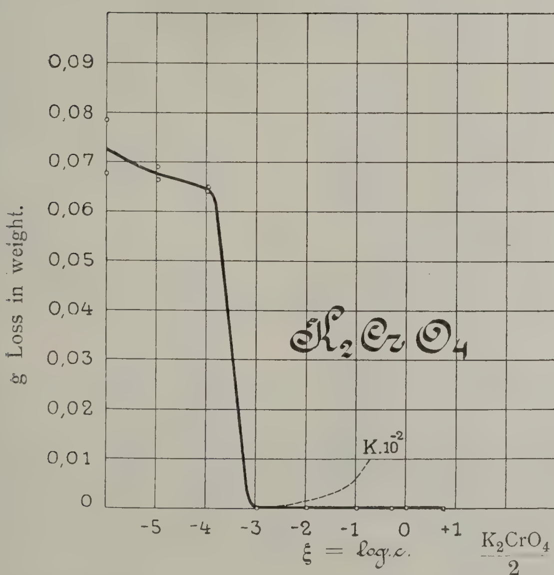


Fig. 6.



——— Loss in weight.

.... Speed constants for catalytic decomposition of H_2O_2 according to Spitalsky.

potassium chromate (fig. 6), sodium acetate, calcium hydroxide. It may however be possible that the peak is not really absent, but that it has not been observed, simply because it lies between the concentrations used in the experiment.

Sodium nitrate solutions, on the other hand, show two such c_h peaks.

No reduction in the corrosion as compared with a distilled water medium, could be found with critical solutions of ammonium acetate, ammonium nitrate and potassium iodate.

Corrosion in critical solutions is in a great majority of cases greater than in distilled water: it is however occasionally less, as for example, with potassium chloride, potassium sulphate, sodium chloride, sodium bicarbonate, sodium sulphate, calcium bicarbonate, calcium chloride, barium chloride.

Table I shows the concentrations c_t of the solutions with which the corrosion is a minimum. These solutions are between distilled water and the critical solutions. It also shows the corresponding value v_t of this minimum corrosion. The table also gives the critical concentration c_h together with the corrosions v_h corresponding to the peaks in the curves.

The values of v_t and v_h are stated in percentages, the action in distilled water being taken as 100. The different electrolytes are arranged in order of the values of v_h and therefore the solutions at the end of the series have, at the critical concentrations, the highest corrosive effect upon iron.

In the neighbourhood of their critical concentration, the solutions show very strong local action: the corrosion being distributed very irregularly over the surface of the iron.

The pronounced irregular local corrosion lends special importance to the "critical solutions". Corrosion of this kind renders the technical use of the iron particularly difficult because the metal is eaten through at places, neighbouring ones remaining uncorroded; hence the life of some of the parts which enter into constructional work cannot be depended upon. The effect upon iron of a liquid, the attack of which is fairly powerful, but regular over the whole surface of the iron may, in certain circumstances, have less dangerous results.

Table I.

Electrolytes classified according to the activity of their critical solutions at temperature of the room.

Series	Electrolyte	Equivalents	Concentration of solution (between distilled water and the critical) having least action		Critical solution		
			v_t %	$c_t \cdot 10^4$	v_h %	$c_h \cdot 10^4$	
	$Ca(OH)_2$	2	absent		absent		All solutions show weaker attack than distilled water
	CrO_3	2					
	$K_2Cr_2O_7$	2					
	K_2CrO_4	2					
	$NaC_2H_3O_2$	1					
1	K_2SO_4	2	80	11·5	88	1150	
2	$Ca(HCO_3)_2$	2	83	5·5	90	27·5	
3	$BaCl_2$	2	84	82	90·5	8200	
4	Na_2SO_4	2	88	6·18	93	618	
5	$CaCl_2$	2	92	2·3	96·5	230	
6	NaCl	1	95	0·17	96·5	1710	
7	$NaHCO_3$	1	92	1·19	97	119	
8	KCl	1	89	134	98	6700	
9	$CaSO_4$	2	91	29 9	98	299 1)	
10	As_2O_3	6	96	1·95	101	19·5	
11	$MgSO_4$	2	82	8·11	102	811—4050	
12	$NH_4C_2H_3O_2$ 2)	1	absent		(104)	(1·3)	
13	$Na_2B_4O_7$	2	93	0·524	104	5·24	
14	K_4FeCy_6	4	93	0·0948	106	9·48	
15	$KMnO_4$	1	88	0·633	106	6·33	
16	$KClO_3$	1	96	0·816	107	8·16	
17	$MnSO_4$	2	90	0·08	107	8·3	
18	Na_2HPO_4	2	90	0·558	107	55·8	
19	K_3FeCy_6	3	95	0·0912	108	9·12	
20	KIO_3	1	absent		108·5	0·47	
21	$NaNO_3$ 3)	1	90	0·1176	109	11·76	
			98	1176	107	5880	
22	NaOH	1	87	2·5	110	25·0	
23	KCy	1	99	1·535	113	15·35	
24	$MgCl_2$	2	86	9·85	114	9850	
25	$KBrO_3$	1	not very marked		118·5	5·99	
26	Na_2CO_3	2	87	1·89	133	189	
27	K_2CO_3	2	90	1·449	134	144·9	
28	$(NH_4)_2HPO_4$	2	99·5	0·1515	142	1·515	
29	$FeSO_4$	2	97	0·072	217	7250	
30	NH_4Cl	1	96	1·87	376	18700	
31	$(NH_4)_2SO_4$	2	91	1·515	509	30300	
32	$(NH_4)NO_3$	1	absent		2390	62500	

1) Saturated solution.

2) Very variable; in some circumstances attack very pronounced.

3) Two c_t and two c_h present.

Local corrosion is very pronounced in the case of the critical solutions of sodium and potassium carbonates and of sodium phosphate. Sodium bicarbonate does not however lead to local corrosion.

Much publicity has been given in technical and scientific literature to the statement that alkaline solutions, such for instance as sodium carbonate and others, in any case afford effective protection against corrosion, but this view is erroneous. As will be seen from the above, the critical solutions of sodium and potassium carbonate not only do not afford protection but cause severe corrosion. Corrosion in these cases, as compared with its amount in distilled water, is approximately as 133 to 100. These two substances stand consequently very high in the series given in table I. Their attack is only exceeded by that of the ammonia salts. The protective effect of alkali carbonates only commences with higher concentrations (fig. 5).

The view often expressed also in the same literature to the effect that the chlorides and sulphates of the alkali metals lead to higher corrosion than pure water, is also wrong. (See table I and fig. 3.)

Ammonium salts at and near their critical solutions, lead to very sharp attacks on iron. The most severe is the corrosion caused by ammonium nitrate.

It may be stated as a general rule that in strengths beyond the critical concentration the corrosive power of the solutions upon iron diminishes (see figs. 3 to 5). In the case of solutions without critical concentrations, such a decrease sets in immediately with the addition of the dissolved substance to the distilled water (see fig. 6).

In some solutions the diminution of the corrosion is on such a large scale that beyond a certain limiting concentration, the iron remains absolutely bright and its loss in weight is practically null. (see figs. 5 and 6). This concentration is styled the “limit concentration“ c_0 and the corresponding solution the “limit solution“.

Table II.

Limit concentration and order of solutions, the limit concentration of chromic acid being taken as 100.

	Electrolytes	Limit concentration c_0 (approximative) $\times 10^2$	Series numbers $\frac{c_0 \text{ of solution}}{c_0 \text{ of chromic acid}}$	Remarks
1	CrO_3	0·02	1	
2	$K_2Cr_2O_7$	0 04	2	
3	K_2CrO_4	0·06	3	
4	KIO_3	0·26	(13)*)	
5	$KBrO_3$	0·33	(16)*)	
6	$KMnO_4$	0·35	17	
7	$NaC_2H_3O_2$	0·40	20	*) Protection not very complete, rust stains being observed upon the iron in the concentrated solutions.
8	KCy	0·84	42	
9	$Ca(OH)_2$	1·09	55	
10	K_3FeCy_6	1·37	68	
11	K_4FeCy_6	1·42	71	
12	$Ba(OH)_2$	2·23	111·5	
13	NaOH	2·50	125	
14	$Na_2B_4O_7$	2·88	144	
15	Na_2HPO_4	3·07	153	
16	$NaHCO_3$	6·54	327	
17	K_2CO_3	7·97	398	
18	$(NH_4)_2HPO_4$	8 33	416	
19	Na_2CO_3	10·39	520	
20	$KClO_3$	42·65	(2132)*)	

The limit concentrations are given in Table II. The values are only to be taken provisionally, seeing that the successive steps of concentrations in the various experiments were larger than was essential for arriving at more exact values. In the most unfavorable cases the error can amount to $90^0/_0$, since the real value lies between thn limits n and n 10, n befing a definite number.

The table shows the following facts:

Chromic acid and its salts are the most efficient protectors against the rusting of iron. Even the very slightest additions of these salts to distilled water suffice to bring about a protective effect (fig. 6).

With chromic acid and potassium dichromate, the extent ot the surface of the iron has an influence on the value of the "limit concentration"; whilst with borax solutions an influence of the kind was not noticeable in the conditions in which the experiment was carried out.

It would appear therefore that there exists a fundamental difference between the protection afforded by chromic acid and chromate, on the one side, and the effect of borax, representing the alkaline solutions, on the other.

Table III.

Attack in saturated solutions of electrolytes having an imaginary concentration limit.

Arranged in order of the values of $\frac{100 - v_s}{c_s}$ (Ratio of protective effect to unit of concentration).

	Electrolytes	v_s Attack of saturated solution (the attack in dist. water = 100)	c_s Approximate concentration of saturated solution at temp. of room	$\frac{100 - v_s}{c_s}$
1	NH_4NO_3	1320	14·44	negative
2	$(NH_4)_2NO_4$	360	8 08	negative
3	$FeSO_4$	162	2·82	negative
4	NH_4Cl	63	5·4	7
5	$MnSO_4$	36	6·75	10
6	$MgCl_2$	2	9·8	10
7	$NaNO_3$	19·5	7·4	11
8	KCl	50	4·0	12
9	$MgSO_4$	22	5·4	14
10	NaCl	19	5·4	15
11	Na_2SO_4	53	(2·5) [1]	(19) [1]
12	$BaCl_2$	39	3·06	20
13	K_2SO_4	76	1·16	21
14	$CaSO_4$	98·5	0·0299	(50) [2]
15	$KClO_3$	0·77	0·608	163
16	As_2O_3	34	0·195	348 [3]
17	$Ca(HCO_3)_2$	66·5	0·0055	6100

[1] Doubtful value.

[2] Doubtful, c_s being still within the critical zone.

[3] Deposition of As on the iron.

It is conceivable in the case of solutions showing no limit concentration, that this limit really lies beyond the saturation limit of water for the dissolved substance; in other words, that there is an imaginary limit concentration. With such solutions, the attack of iron can practically never be reduced to zero; it always remains at a certain lower limit v_s.

Such lower limits are given in Table III, also the approximate concentration of the saturated solutions at the temperatures of the room. Column 5 gives the calculated values for $\frac{100-v_s}{c_s}$, namely the protective effect of the solution dependent upon the unit of concentration. The various solutions are arranged in the table according to these values; the higher the latter are, the greater the protective effect of the corresponding electrolyte. Ammonium chloride in strong solutions has a relative protective effect, notwithstanding its energetic attack when the solution is critical. With ammonium nitrate, ammonium sulphate and iron sulphate, on the other hand, the attack of the critical solution is so energetic that the protective effect which occurs above critical concentration, cannot reduce the attack below that occurring in distilled water.

Since, according to the experiments referred to in the foregoing paragraphs, the quantity of oxygen in the solutions exercises an important influence upon the rust formation, since also the capacity of the electrolyte for dissolving oxygen decreases with the increase in concentration; it is to be expected that with increased concentration the attack on iron should decrease.

Fig. 3 shows, as well as the $\xi \dot{v}$ curve, also that for the solubility of oxygen according to Geffcken; it will be seen that they substantially correspond.

It is probable that with solutions having no limit concentration the attack upon iron depends, in the first place, upon the quantity of dissolved oxygen, while, with solutions with such a limit concentration, other influences also play a part.

E. Electrolytic potential differences between iron and various solutions.

The potential differences measured between iron and the liquids are referred to the Oswald normal electrode. The iron and liquid were maintained in the most complete state of immobility, seeing that motion of either exercises a great influence upon the potential difference to be measured. The E. M. F. was recorded both as to its variation with time, and with the concentration of the electrolyte. The curves in which time is the abcissae and the potential the ordinates are

called the z E curves. From the records of a whole series of such measurements the electrolytes can be divided into the following two groups:

I. Group. Electrolytes without a limit concentration: For all concentrations they have negative values[1]) of E above -- 0,2 volt. The zE curves rise from lower to higher negative values.

II. Group. Electrolytes having a limit concentration: a) In these with solutions below the limit concentration, the value of E is above — 0·2 volt. The z E curves rise as in group I, towards the negative side of the diagramm. b) From the limit concentration upwards, however, the z E curves have a reversed course; they sink down towards the positive side and remain below the limiting value of — 0·2 volt. Saturated solutions of hydrate of soda, potassium cyanide and potassium carbonate, only, form exceptions as they show the same course for the zE curves as is the case with solutions under groups I and II a, strikingly large negative values being attained without rust formation.

The limit concentration c_0 thus corresponds to a limit value E_0 for the potential difference, which value lies pretty close to — 0·2 volt. This number has been obtained purely empirically. In order to draw from the course of the z E curve of an electrolyte a conclusion as to whether the solution attacks iron or not, the following empirical rule can be followed:

If E remains less than $E_0 = -0{\cdot}2$ volt in the solution experimented with, no corrosion will occur at all. If, on the other hand, E lies above — 0·2 towards the negative side, it cannot readily be decided whether corrosion occurs or not. In this case, there remains nothing further to be done but to follow directly the experiment described in paragraph D. This method, at all events, is the safest and is to be recommended in every case.

The authors adhere to the electrolytic theory of corrosion according to which rust formation sets in as per the equation

$$Fe + 2H^{\cdot} = Fe^{\cdot\cdot} + H_2 \qquad (1)$$

This reaction can only take place in the direction shown when the potential value of the iron in the solution considered, oxygen

[1]) The negative values of E are plotted above the zero line, the positive values below this zero line.

being completely excluded, is less than the potential value E_h of the hydrogen in the same solution. The reaction represented by the above formula must, however, necessarily come to a standstill, as soon as the saturation limit of the liquid for Fe (OH_2) is reached.

This only applies when there is no access of oxygen to the solution. In the presence of sufficient oxygen, the $Fe(OH_2)$ will be oxidised to higher oxides, the solubility of which in the solution is smaller. These are separated out of the solution in solio form and in quantities corresponding to the difference in solubility. A further solution of Fe to $Fe(OH_2)$ can then take place anew, the solution being no longer saturated with the latter. Upon the admission of oxygen, oxidation is effected afresh and it continues regularly so long as sufficient liquid and oxygen are present.

As the process expressed by the formula 1, comes to a standstill with very low $Fe^{\cdot\cdot}$ concentrations (the authors conclude from their researches and calculations that the limit of concentration amounts to $10^{-7\cdot5}$ $Fe^{\cdot\cdot}$), the small amount of hydrogen set free is not perceptible. When there is admission of oxygen, the hydrogen is probably oxidised to water, seeing that in the corrosion experiment in which 0·315 grammes of iron were transformed into rust, the gases carried along with the air contained no hydrogen.

On the basis of a whole series of measurements the authors come to the conclusion that by measuring the potential of iron in electrolytes which do not contain $Fe^{\cdot\cdot}$ ions, it is not the true potential of the metallic iron which is measured, but the potential difference of an oxygen electrode formed upon the iron.

This throws light upon the varied and involved phenomena which influence the E. M. F. in so far as they apply to an electrolyte without a limit concentration. Conditions with electrolytes having a limit concentration require still further clearing up. For a more detailed review of the question, readers are referred to the original paper of the authors.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

XVII4

A PLEA FOR INTERNATIONAL INVESTIGATION CONCERNING PROTECTIVE COATINGS FOR IRON AND STEEL.

By **J. Cruickshank Smith**, B. Sc., F. C. S., London.

The protection of metallic structures is a subject of such great and obvious importance not only to Architects and Engineers but also to property owners that it is somewhat surprising that until a comparatively recent period there were few observed scientific facts and authenticated records available as guides in the selection and valuation of protective coatings. The subject, however, has recently been engaging the attention of technical men in various parts of the world, and as there are indications that some of the results arrived at may in course of time modify or even revolutionise existing opinions and methods, the time seems opportune to remind this Association of the position as it exists to-day, and to suggest a line of investigation which appears likely to result in a considerable advance in our common fund of technical knowledge while it falls within the scope of the objects of the International Testing Association. If a statement of the case should prove instrumental in arousing interest in this important subject and should induce discussion which will culminate in action, my present purpose will have been attained.

Let me remind you that the factors which, in the main, govern the efficiency of a protective coating for its specific purpose fall under one or other of four heads:

1. The chemical composition of the paint.

2. The physical and mechanical properties of the paint and of the protective film produced therefrom.

3. The conditions and influences existing in or produced by the surface to which the paint is applied.

4. The conditions depending on exposure, climatic and atmospheric influences and the like; which we may term service exposure conditions.

In order to clear the ground I propose to refer briefly to each of these topics separately, and to indicate what appears to be the present trend of scientific and technical opinion in respect of each.

1. Composition of the Paint.

Although opinions vary as to what is theoretically the best pigment, or more correctly combination of pigments, for the manufacture of protective coatings, the general consensus of technical opinion seems to be gradually coming to be that, with certain more or less obvious reservations, the composition of the paint is less important than its physical state and that one pigment or blend of pigment is more efficient than another as the basis for a protective paint mainly according to the degree in which it tends to produce certain definite physical and mechanical effects in the ultimate protective film. The problem that remains is the selection of that blend of pigments, suspended in a suitably adjusted vehicle (the paint as a whole possessing the necessary physical properties), which will under known conditions as to exposure and climatic conditions yield a satisfactory protective film. Only exposure tests can solve this problem.

2. Physical and Mechanical Properties.

It is now generally accepted that such factors as fine state of division and uniformity in size of the pigmentary particles, viscosity of the paint, elasticity and strength of the paint film, and impermeability of the paint film to moisture and gases are of paramount importance in determining whether or not a particular paint will satisfactorily effect the purpose of a protective coating. In this connection I would direct attention to the admirable scientific work recently accomplished and still being conducted by the scientific section of the Paint Manufacturers Association of the United States and also by the various committees of the American Society for Testing Materials. The official publications of these

two bodies teem with technical matter which no-one who claims to be up-to-date in his knowledge of this subject can afford to be ignorant of.

3. Nature of the Surface on which the Paint is applied.

The most recent researches on the subject of the corrosion of iron and steel and in particular the development of the electrolytic theory of corrosion, which has been greatly advanced by the work of Dr. A. S. Cushman and Dr. W. H. Walker and others, still further strengthen the view that, while the composition of a paint or pigment cannot be disregarded, the physics of paints and paint films is a subject of at least equal importance. Questions also arise as to what essentially should be the difference (if any) in composition and physical properties between coatings designed for wood and for metal respectively. Only exposure tests will yield reliable information on these points.

4. Exposure under Service Conditions.

We are here brought face to face with problems which are perhaps the most difficult to solve of any in connection with protective coatings, not only by reason of the fact that conclusions based on the results of exposure tests are only available after a comparatively long period of time, but also because so many factors enter into the question that we are at once plunged into the logical difficulties that arise from plurality of causes and mixture of effects. Nevertheless the American Societies to which I have referred have not shrunk from facing the problem, and the results which they have obtained even in a comparative short period are such as to warrant the assumption that more extended experiments conducted in other parts of the world will yield exceedingly valuable information.

I now come to the practical suggestion which I desire to submit to this Association. It is that in each country containing an affiliated branch of the Association (or in every branch specially interested in the subject under review), a committee be appointed in order to determine whether a series of carefully planned and scientifically conducted exposure tests under service conditions with various paints of known composition and properties can be carried out in order to arrive at a wider and mare accurate

knowledge of the specific conditions which induce the destruction through climatic and atmospheric causes of films of protective paint, and of the best means to be adopted in the compounding and application of protective paints to counteract such destructive influences.

As this Association is no doubt aware a most elaborate series of exposure tests is now in progress at Atlantic City in the United States of America. Even already the results which have been published in connection with this series of experiments are valuable, and they may be utilised in framing further experiments of the nature I suggest. I would emphasize the fact that whatever the ultimate results of the Atlantic City experiments may be, they cannot do more than demonstrate the comparative merits of different paints under the exposure conditions that exist at Atlantic City. Now when we consider the enormous variations in such contributory causes to destruction of protective coatings as humidity, extremes of heat and cold, direct sunshine, atmospheric impurities and the like that exist in different localities we are led to enquire 1. what is the most efficient paint all round for withstanding these diverse destructive influences and 2. what variation in the paint is best calculated to enable it to withstand any one of these influences acting as a dominating destructive influence. It is a well known fact that a paint or varnish or enamel may last well and be an efficient protective medium in a dry equable climate and yet may be readily destroyed when exposed to alternate spells of dry and wet or to rapid and great variations in temperature. I submit that such points as these can only be satisfactorily settled by designing and carrying out a series of exposure tests conducted with selected materials, whose composition and physical properties are known, in various parts of many countries and by collecting and tabulating the results obtained.

It would appear that the personel and organisation necessary to conduct such an investigation is possessed in a preeminent degree by the International Testing Association, and if this Congress after discussing the proposition decides to leave it in the hands of the members of each country to make their own arrangements, subject to some general direction or recommendation by the Association as to the modus operandi, there is little doubt that tangible results will accrue, and that the Association will accomplish a useful public and international service.

A practical outcome of my suggestion would be the appointment in each country of a committee containing representatives of the Association and also persons representing large consumers, such as railway companies, constructional engineers, public bodies and Government departments who use protective paints largely. Paint Manufacturers should also be represented, and each committee should contain a chemist and a paint expert who might act as director of tests. This committee would then, after careful consideration of the whole problem carry out a series of service exposure tests under observed conditions. Possibly in the first instance this series of tests might be discussed and the general principles to be adopted agreed upon by the various committees acting in conference. In order to make the experiments useful the materials employed as well as the surfaces on which these materials would be applied should be, as far as is practicable, identical in each country. With regard to the composition of the protective coatings the following list, which is given merely in the way of suggestion, includes typical materials whose properties in the way of protection might usefully be compared.

1. Genuine white load in raw linseed oil.
2. Genuine oxide of zinc in prepared drying oil.
3. Mixture of genuine white lead, oxide of zinc and barium sulphate in prepared drying oil.
4. Oxide of iron with or without admixture with native ferruginous earth (ochre) in prepared drying oil.
5. Hydrated calcium sulphate tinted with oxide of iron and carbon in prepared drying oil.
6. Red lead and carbon in a suitable drying medium.
7. Prepared graphite in a suitable drying medium.
8. Any special paint offered by manufacturers: the composition to be determined by the committee but not to be publicly disclosed except with the manufacturers' consent.

The surfaces on which these materials would be exposed might consist of wood, malleable iron and steel, each conforming rigidly in nature and size to an agreed specification.

The conditions as to exposure, altitude and the prevailing climatic and atmospheric conditions during the period of the tests would have to be recorded periodically and accurately by some local observer.

The question of finance cannot be overlooked, and it is possible that the funds of the Association would not be sufficient for meeting the expense involved in carrying out the proposed investigation. In view, however, of the important public utility of the work it is extremely likely that grants would be obtained in various countries from scientific, industrial, or public bodies. With regard to Britain I feel sure that neither this feature nor the question of obtaining suitable representatives of various interests to serve on the committee would be a matter of insuperable difficulty.

During the interval between the present Congress and the next Triennial Congress some important authenticated results would probably be in the hands of the various committees and these could then be submitted at the next Congress as an International report.

Finally I wish to emphasise the fact that there is nothing in the whole of this proposition which has not already been attempted and partly carried out by the American Society for Testing Materials, and I venture to submit that it is only when engineers and other paint consumers in various parts of the world have made up their minds seriously to face the problems connected with the protection of structures for which they are responsible in some definite and exhaustive manner that the selection and application of protective coatings will be raised from its present position of being a mere haphazard matter of rule of thumb, and will be placed on a scientific and reliable basis.

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I4

"SLAG ENCLOSURES" IN STEEL.

By **Walter Rosenhain** B. A., D. Sc., Teddington (England).

The object of the present paper is to call attention to the importance of further and closer study of the influence which is exerted upon the strength and safety of steel by the presence within its mass of numerous enclosures of non-metallic bodies which may conveniently be grouped together under the term of "slag enclosures". These enclosures have been studied to some extent by a number of metallurgists, including H. Le Chatelier[1]), J. O. Arnold[2]), T. Andrews[3]), J. E. Stead[4]), Captain Howorth[5]), H. Fay[6]), E. F. Law[7]) and the present author[8]), and some of these have drawn attention to the fact that failures in steel objects have repeatedly arisen from the presence of these enclosed impurities. While some metallurgists appear to regard these enclosures as practically harmless, the present writer has repeatedly

1) H. L. Chatelier: "Sulphide of Iron, its Properties and its Condition in Iron." Bulletin de la Société d'Encouragement, September 1902.

2) Arnold & Waterhouse: "The Influence of Sulphur and Manganese on Steel", Journ. Iron and Steel Institute, 1903, I.

3) Andrews: Engineering, July 10, 1906, and numerous other papers.

4) Stead J. E.: "Iron and Steel Magazine", vol. IX, Nr. 2, p. 105, Feb. 1905.

5) Howorth: "Greenish Coloured Markings in the Fractured Surfaces of Test Pieces", Journ Iron and Steel Institute, 1905, II.

6) Fay: Amer. Soc. for Testing Materials, Proceedings, vol. III, 1908.

7) Law: "Non-Metallic Impurities in Steel", Journ. Iron and Steel Inst., 1907, II.

8) Rosenhain: "Deformation and Fracture in Iron and Steel", Journ. Iron and Steel Inst., 1906, II.

expressed the opinion as to their dangerous nature[9]) and recent experience of some definite cases of failure arising from the effects of slag enclosures lead him to bring the subject before the International Association.

The detection of the presence of slag enclosures in steel is comparatively easy, the most direct method being an examination of a micro-section of the material. In the case of material which has been rolled or forged it is, however, almost essential that the section examined should be a "longitudinal" one, i. e. cut along a plane parallel to the direction of general extension, such as the

Fig. 1.
"Slag enclosures" in a section of gun-steel, unetched. Magnification 150 diameters.

direction of rolling in a bar or a rail, since in transverse sections the inclosed impurities appear as very minute dark spots which may easily escape notice.

The microscopic appearance of some typical forms of slag-enclosures are shown in Figs. 1 to 6 which are all taken from objects which have failed in service as a result of the presence of an excessive quantity of these enclosures. Figs. 1 and 2 represent sections showing these inclosures in the steel of a large

9) Institute of Automobile Ingineers, Feb. 13, 1907, "The Strength and Structure of Alloys."

gun[10]) as they appear when the steel has been polished, but not etched. At least two types of enclosures are seen in these sections; one is the "dove grey" sulphide of manganese as described by Arnold, Stead and others, but the other is not so readily identified. It makes itself apparent in the form of numerous black patches, generally very minute, but very widely scattered. In many cases there is no doubt that these patches are simply holes from which the brittle material has been torn during the polishing process, but in other cases the dark substance itself is still present. This substance may be the silicate of manganese indicated by

Fig. 2.
Slag enclosures in gun-steel. Magnification 150 diameters.
Specimen not etched.

Stead, but it is also possible that it may consist either of oxides or silicates of iron. It is interesting to note that in this particular case the enclosures are not segregated in the ferrite areas, but are fairly uniformly distributed through both ferrite and pearlite.

Figs. 3 to 6 represent the appearance of the slag-enclosures in sections of a rail which failed in service; in this case they are

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[10]) The steel of this gun has already been fully described by the present author in a paper on "The Study of Breakages" at the Brit. Assoc. for the Advancement of Science, Dublin, 1908. Reprinted in "Engineering", Sept. 4, 1908.

both very large and very numerous. Fig. 3 shows enclosures of sulphide of manganese with a large number of black patches and holes corresponding to a second type of enclosed impurity. Fig. 4 shows a very large enclosure consisting principally of sulphide of manganese, while Fig. 5 shows this same area after the specimen has been etched with picric acid, this latter view revealing the manner in which the slag enclosure is situated in the centre of a relatively wide band free from pearlite (sometimes called a "ghost"). Fig. 6 shows another example of a slag enclosure in the same rail. Mechanical tests carried out on this material

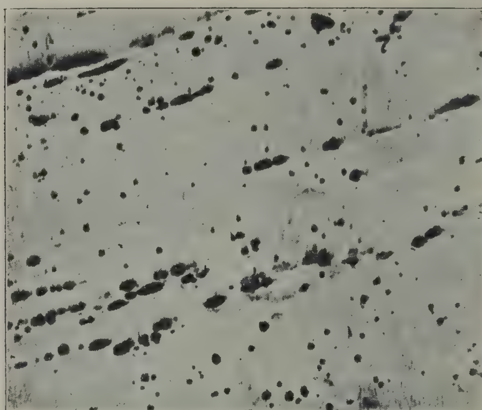

Fig. 3.

Slag enclosures in the longitudinal section of the web of a rail which failed in use. Specimen un-etched. Magnification 150 diameters.

showed it to be excessively weak in those directions which the presence and shape of the enclosures indicated as lines of weakness.

The observation that the enclosures of sulphide of manganese are usually closely associated with the other slag-enclosures present, the two often appearing together in one lump or globule, places another means of examination at our disposal. The distribution of sulphide of manganese is readily ascertained by taking what is known as a "sulphur print". The most convenient method for this purpose is that suggested by Baumann, who applies a sheet of photographic bromide of silver paper to the steel after

Fig. 4.

Large slag enclosures (principally sulphide of manganese) in a longitudinal section of a steel rail, specimen not etched. Magnification 150 diameters.

Fig. 5.

Same enclosure as in Fig. 4 after etching with picric acid. The true contours of the enclosure are revealed by the removal of the ferrite which had been "smeared" over it. Also shows the position of the enclosure in a carbonless band or ghost.

moistening the paper with dilute sulphuric acid[11]) The print thus obtained varies in depth according to the distribution of the sulphide in the steel, and sections for microscopic examination can then be cut from those parts of the section corresponding to the darkest part of the print. It is essential, however, to cut away the surface layer of metal which had been exposed to the acid, as otherwise the observer will only find the empty holes from which the sulphide has been dissolved.

While the work of those cited at the beginning of this paper has already thrown much light on the nature of these enclosed

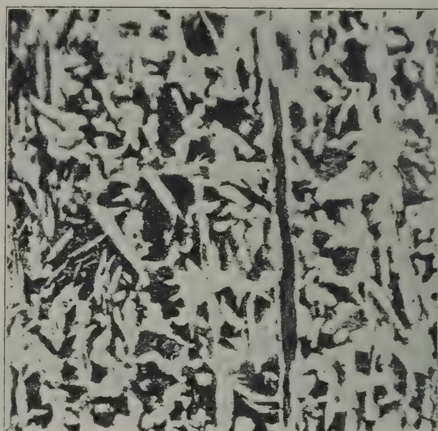

Fig. 6.
Elongated and duplex slag enclosures in a steel rail, specimen etched with picric acid. Magnification 150 diameters.

impurities, it appears that there is still room for doubt as to their true nature and origin. Thus the duplex appearance of some of the slag-enclosures in steel is currently accounted for on the view that these duplex masses consist of sulphide of manganese embedded in silicate of manganese, but the present author has observed

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[11]) Although the method here ascribed to Baumann is perhaps the most convenient, the author believes that one of the earliest workers to make contact sulphur prints was Heyn (Berlin) who utilised thin sheets of silk saturated with acidified mercuric chloride, and similar means of obtaining sulphur prints long before Baumann's suggestion of using photographic paper was made.

instances of duplex enclosures in which neither constituent was readily soluble in acids. A comparison of these enclosures with the "slag" or "cinder" enclosures which are so typical of wrought iron also furnishes some interesting facts. In wrought iron, while practically no manganese is present, there is always a large amount of enclosed non-metallic matter, and this sometimes presents a very well-marked duplex structure. An example of this kind, taken from some Staffordshire iron, is shown in Fig. 7. In this case, although sulphide of iron may be present, it seems probable that the constituents are two different silicates — or possibly oxides — of

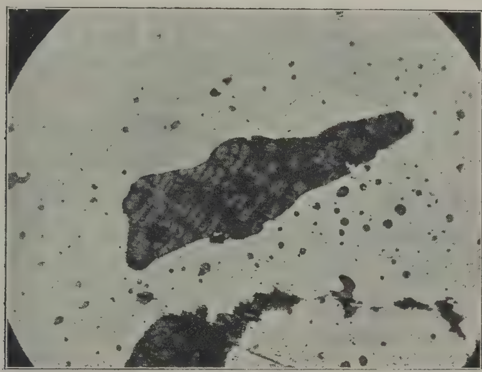

Fig. 7.

Slag enclosure in Staffordshire wrought iron; the light constituent shows well-defined dendritic structure. There is no manganese present in this specimen. Magnification 200 diameters.

iron. Further study of these impurities is obviously required, particularly as it will be seen on studying the papers cited above that our present knowledge of their nature depends principally upon chemical analyses of residues obtained after selective solution of the metal, and the uncertainty of results obtained in that way is well known.

Although a full knowledge of the nature of these bodies is essential as a preliminary to the investigation of their mode of origin, some considerations on that subject are justified by the knowledge already available. Thus Stead suggests that these enclosures in the case of steel result from the introduction of

oxygen into the steel either during the melting or the teeming process, this oxygen reacting with the manganese and silicon to form the manganese silicates, while the sulphur already in the steel combines with the manganese in the manner shown by Arnold and others. This is, of course, a possible and in many cases a perfectly probable source of these bodies; in fact, so far as the sulphide of manganese is concerned there is little need to look further. The only remedy for this class of enclosures is to keep the molten metal at rest for a sufficient time after the addition of manganese to allow the sulphide to rise to the surface, and in spite of the very considerable difference of density, this probably requires a much longer time than would be at first sight anticipated. The entire protection of the steel from oxygen during the teeming operation is the obvious remedy for the formation of silicates on the view of Stead, although this remedy appears difficult to apply in practice. The writer would, however, point out that steel is also liable to contamination with impurities of a siliceous nature from other causes. One of these is the possibility of incomplete separation of slag from metal in the furnace or the converter; the violent "boiling" of the steel must necessarily involve a good deal of intermixing of slag and metal and here again the time required for complete separation is probably longer than one might suppose, particularly where the smaller particles or globules of slag are concerned. Further, in the course of its passage from the furnace into the ingot-moulds the steel runs several risks of contamination with siliceous matter; the tapping-hole of the open-hearth furnace is one of these, as also the gutter along which the steel flows into the ladle and the ladle itself, with its stopper, all present possibilities of introducing non-metallic impurities into the metal, while — finally — where the process of casting in inverted ingot-moulds is used, the steel comes into contact with conduits of refractory material. From all these sources the molten steel will and does readily absorb any detachable particles and as the steel is in rapid motion, there is little time for the lighter particles to begin to separate themselves, until the metal is at rest in the ingot-mould, where it probably begins to solidify before the smaller particles have been able to free themselves. With these considerations in mind, the very great frequency with which non-metallic impurities are met with in ordinary steel can no longer be regarded

as surprising and it appears probable that if some of these risks of contamination were minimised the prevalence of slag enclosures would be considerably reduced. For this reason the further and exact study of their nature and mode of origin appears most desirable.

While some of the workers whose papers have been cited above are evidently alive to the serious results which may and do arise from the presence of these impurities in steel, some metallurgists appear to look upon these enclosures as more or less normal and harmless, much as they might regard cinder or slag in wrought iron. From this point of view it may be pointed out that there is a considerable and vital difference between the behaviour of "slag" in wrought iron and in steel. In the former material (iron) the metal itself is extremely soft and ductile and much less sensitive to local mechanical injury than the stronger but in some ways more sensitive steel. Even in steel, it is true, the non-metallic impurities generally tend to segregate in regions or bands of ferrite, as in the case shown in Fig. 5 above, but where these impurities are embedded in the harder pearlite they are in contact with a material wich cannot readily adapt itself to an essentially incompatible neighbour.

The deleterious influence of slag-enclosures in steel has perhaps escaped attention to some extent owing to the fact that in ordinary tensile tests, taken in a direction parallel to that of rolling, these enclosures only occupy a very small proportion of cross-sectional area and possess a tapered shape which allows of gradual distribution of the stresses imposed on the material. Even in such tests, however, the writer has shown[12]) that the slag-enclosures are broken up into numerous pieces prior to the fracture of the metal. If now we consider the case of transverse stresses, or of shock or vibration, it will be seen that these enclosures will be fractured as soon as the metal undergoes any material deformation and then each such enclosure practically represents an internal fissure which is ready to extend — and actually does extend — in any direction compatible with the applied stresses.

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[12]) See paper cited above, note 8, p. 1.

The photo-micrographs in the earlier part of this paper have been taken — as has already been indicated — from two cases of actual service failure arising from the causes just indicated, and these two cases are typical of a number of others which occur in practice. The further study of the nature of these impurities and of the means of avoiding their presence in steel is thus a matter of considerable importance to users of that material.

Errata:

Foot note 1: H. Le Chatelier, not H. L. Chatelier.
Foot note 9: Engineers, not Ingineers.
Description of Fig. 1, 2, 3, 4, 6:
Magnification 100 Diameters, not 150.
Fig. 7: 133 Diameters, not 200.

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III5

IMPACT TENSILE TESTS.

By M. **Pierre Breuil,** Paris.

Translated from the French original by Arthur R. Liddell, Charlottenburg.

Abstract [1])

In this work the author has endeavoured to show the relations which exist between the results obtained by static and dynamic tensile tests respectively. The attempt made to abolish tensile tests and replace them by impact tests on notched bars suggested to the author the desirability of ascertaining whether the tensile tests are really powerless to reveal brittleness in metals, as has been asserted.

It has always seemed irrational to the author, that impact tests on notched bars should be compared with static tensile tests; the two kinds of test determine the presence of properties which are not of the same nature and which are not comparable with one another. It seemed indispensable to ascertain whether the effects of an impact are the same as those of a test slowly applied to one and the same metal, but for this it would be necessary to choose bars identically the same and to apply to them the same method of testing (tensile compression, bending, etc.).

Mr. Hatt and Dr. Stanton have already shown by their experiments, that there is little difference between the results of static and dynamic tensile tests respectively; M. Breuil, using bars without notches, like these authors, comes to the conclusion

[1]) The original paper is published in the "Supplements to the Congress Papers".

that the two kinds of test almost always give the same results, but that there are metals which do not follow this law, that is to say, metals which may be good from the point of view of static strains and bad from that of dynamic ones. This conclusion is not new, but it may be noted with interest, because it has been arrived at by means of the tensile test, which has been looked upon as ill adaptedto the giving of this information.

M. Breuil's experiments show that notched bars, tested under the same conditions as others without notch, have not shown this difference in the properties of the metal.

In the opinion of the author it would be better to ascertain the brittleness of a metal by testing it in small bars by an impact tensile test; in this way it is possible, as in the case of the tensile slowly-applied test, to measure the elongation and contraction of the metal, and to compare these with the elongation and contraction in the slowly-applied test. It must, of course, be understood that the amount of work performed in these quick tensile tests should be measured and its amount brought into relation to the volume of the metal submitted to deformation. M. Breuil recommends little tensile-test bars with a sectional area of 50 mm^2 and a prismatic length of 60 mm, provided with gripping ends of such section that the deformation is localized in the body of the sample.

Most steels do not require more than 30 kilogrammetres per cubic centimetre of metal for their rupture, and, in contra-distinction to what occurs with the notched bars subjected to the impact test, the complete rupture of the samples of metal by the application of the tensile strain is always a matter of certainty, so that more exact measurements can be obtained.

On the other hand, M. Breuil believes he can demonstrate that the differences found to exist between the amounts of work done in static and dynamic ruptures respectively are due to the heating of the points of fracture in the impact tests.

For the results of the tests, reference may be made to the original report.

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III 7

COMPARATIVE STATIC AND DYNAMIC NOTCHED-BAR BENDING TESTS.

By **A. Leon** and **P. Ludwik.**

From: Mitteilungen des mech.-techn. Laboratoriums der k. k. techn. Hochschule, Vienna, 1909.

Translated from the German by Dr. H. Borns, London.

The object of these experiments was the study of the relations between static and dynamic bending tests made with plane bars and with bars notched in different ways (see Fig. 1). The materials investigated are cast iron, ingot iron and mild steel. Bars of the shapes *a*, *b*, *c*, *d*, *e* were made of each of these materials. The bars *a*, *b*, *c*, *d*, *e* were subjected to static tests, the bars *a*, *d*, *e* to dynamic tests. In order to render the tests comparable, the static and dynamic bending tests were conducted at the same distance between clamps and with the same rounding of the supporting and bearing piece knife edges. In the static tests the complete diagram was plotted, in the dynamic tests only the work done in fracture.

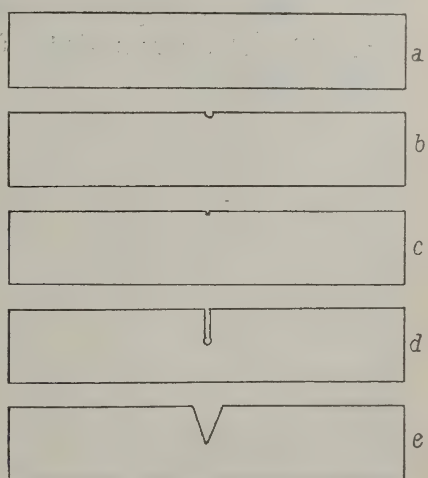

Fig. 1.

The following are the chief conclusions:

1. In static tests the deflection (both the maximum deflection and the total deflection) is much more dependent upon the shape of the notch, than upon its depth.

2. At equal depths the round notches permit of much larger deflections than the sharp-angled notches.

3. With deeply notched bars fracture ensues more gradually than with shallow notches or plane bars.

4. The influence of the kind of notch upon the work done in bending may be very different with static and with dynamic tests.

5. The amounts of work done in static bending and in dynamic bending are not in any uniform relation, and there is not even approximate proportionality with the same materials or with the same kind of notches.

Consequently there can be no uniform relation between static tensile test and notched bar impact test.

6. The ratio of dynamic to static work done in bending ranged, according to material and kind of notch, between 0·6 and 3·5.

7. Different ways of conducting the bending tests (static or dynamic) and different kinds of notches lead to entirely different quality estimates.

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III 8

NOTE ON THE RUPTURE OF NORMAL CYLINDRICAL TEST SAMPLES BY LONGITUDINAL IMPACT.

By Mr. **P. Wélikhow**, Moscow.

Translated from the French by A. R. Liddell, Charlottenburg.

For the determination of the degree of strength possessed by different materials of construction to resist impact or dynamic load (for the determination of their brittleness), quite a series of testing methods, in which metals are subjected to impact, have been made use of.

The experiments, whether in case of impact or of static tests, can here be made by the application of tensile or of compressive strains, or by the bending of the samples. Up till now, however, the impact tensile tests have not been very extensively resorted to, in spite of the fact that apparatus designed for their application by Professor Martens (Mitteilungen aus den königlichen technischen Versuchsanstalten zu Berlin 1891, Vol. IX, part 1) fully justifies their employment and gives very good results (see below).

In recent years the entire attention of experimenters has been given to the compression, and espicially to the bending of the samples by impact. These two latter methods, however, have a great many essential defects, and the results of the experiments cannot altogether be compared with those of static tests.

As final result of each impact test, the work done in the destruction of the sample is determined and referred to the sectional unit. The determination of the work done at the impact compression test is a very troublesome process; for one portion of

it is absorbed be the useless resistances to fracture, and the plastic materials do not break asunder under the impact, but become flattened. The determination of the work is accordingly made only under certain circumstances. Moreover the impact compression test has, as a matter of fact, been almost entirely given up.

Extensively as the impact bending test is applied, and carefully as its nature and procedure are studied on account of the manner in which it comports with the design of the better types of testing machines, it possesses the same defects as these and some additional ones which from the theoretic point of view are still greater.

In the first place, the bending test is made by means of a load concentrated at the middle of the bar, which latter is of considerable height in proportion to its thickness; it is well known what complicated phenomena are produced in the test-sample in similar cases, and how exact theory differs from the ordinary elementary theory of bending.

Secondly, the work done in the rupture is referred to the unit of the cross section of the sample, in order to determine the value characterising the strength of the material to resist impact. For the work of bending bars of uniform section, however, we have a familiar, though somewhat complicated formula, which is not indeed quite applicable beyond the limit of elasticity, but which shows that the work of bending is proportional to the volume, and not to the cross sectional area of the bar. Besides it must be recognised, that the test methods in actual use, although under certain conditions they yield some interesting results, give the qualitative and not the quantitative determination of the property under observation, and do not agree with other testing methods.

Besides, the actual impact test enables a judgement to be formed only upon the brittleness of the material and does not provide means for determining its other properties.

Without denying that the impact bending test gives very interesting results and deserves to be further studied, I may at the same time be allowed to recommend the study of the impact tensile test, which, as I conclude from my own tests, is able to give very true characteristics of the mechanical properties of the sample tested, and is found to be in direct agreement with the

fundamental tensile test. This test yields almost all the data obtained by the statical tensile test; but the cost of the impact apparatus (with falling weight) is considerably less than that of a 50ton tensile-test machine such as that of Mohr & Federhaff.

The procedure followed in our tests was the following: In the mechanical laboratory of the Imperial Engineers' School of Moscow there was a drop-weight apparatus of the same type as that described in the Communications from the Testing Station at Berlin (see Figs. 1 and 2). This drop-hammer was installed with the greatest care in 1899, and since that time its normal position has been constantly checked; it is continually at work, being used for the study of dynamic load and of the oscillations of the elastic bodies subjected to impact (see my works on this subject in the "Annales de l'Ecole Impériale des Ingénieurs, Moscou. Unofficial part, Iv. II, 1908).

For the rupture of the impact-test samples the following preparations were made:

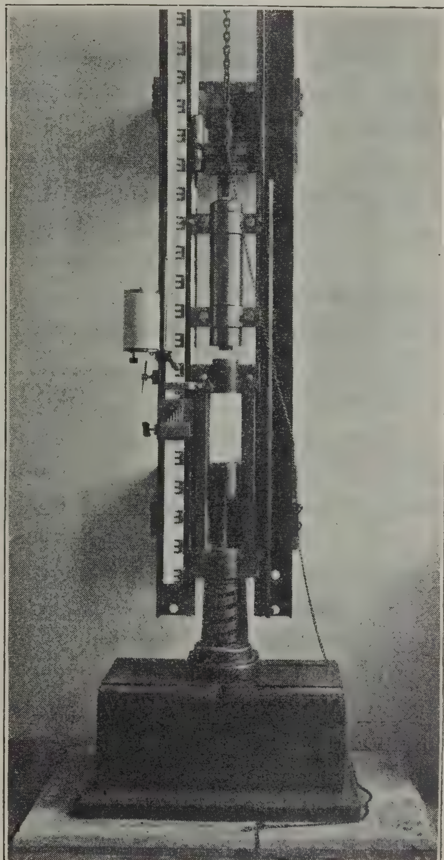

Fig. 1.

On the establishment of the apparatus, we at first placed no sample in it, but, after raising the frame which holds the lower part of the sample and directly takes the impact to a sufficient height, we only placed under the frame a triple spring of the standard pattern used on wagons, which had previously been carefully graduated under a press. The graduation of the spring was effected in the manner, that it was placed under the press of

the hydraulic testing machine and submitted to a steady load, its contraction under different loads being at the same time determined by means of a diagram. It is evident that the area of the diagram calculated up to any given contraction gives the work required by the formula $T = {}^1/_2 P \cdot f$ for the compression of the spring.

In this manner diagrams were made of the work absorbed by the spring up to different contractions. Then the monkey was allowed to fall on the triple spring from different heights 1 m, 2 m and 3 m. Theoretically the amounts of work accumulated in the monkey with its weight of 56 kgs. ought to be 56 kgs. per 1 m, 112 kgs. per 1 m, and 168 kgs. per 1 m respectively.

In effect the least contraction of the spring observed after these falls was:

for 1 m = 38 mm, which corresponds with 31 kg per meter of work done,
„ 2 „ = 53 „ „ „ „ 64 „ „ „ „ „ „
„ 3 „ = 63 „ „ „ „ 104 „ „ „ „ „ „

Consequently the work accumulated by the monkey and absorbed by the spring is considerably less than that due to the height of fall. The reasons for this are the following:

1. in falling, the monkey rubs against the guides, and this accounts for the loss of a portion of the work;

2. some part of the work is absorbed by the deformation of the monkey itself and by that of the frame.

In each of the cases, however great the losses may be, they can be calculated exactly by our testing methods; for the spring undoubtedly takes up the quantity of work represented by its contraction.

It may be noted, that the amount of the contraction of the spring was determined for each height of drop by numerous experiments, which gave concordant results and that the determination of the amount of the contraction itself is very easily and exactly effected by means of a simple appliance consisting of a row of vertical indicators of different heights passed loosely through openings in a wooden board. The load caused a lowering of the indicators, which in the case of some of them was considerable, and which thus showed the corresponding contractions of the spring. The indicators not lowered by the load in its fall remained at the same level and thus enabled the amount of the compression

to be checked. The indicators were not lowered by the monkey itself, but by the frame (see Fig. 2), which haas no acceleration. The indicators cannot therefore receive acceleration and they thus exactly indicate the amount of the compression. This method

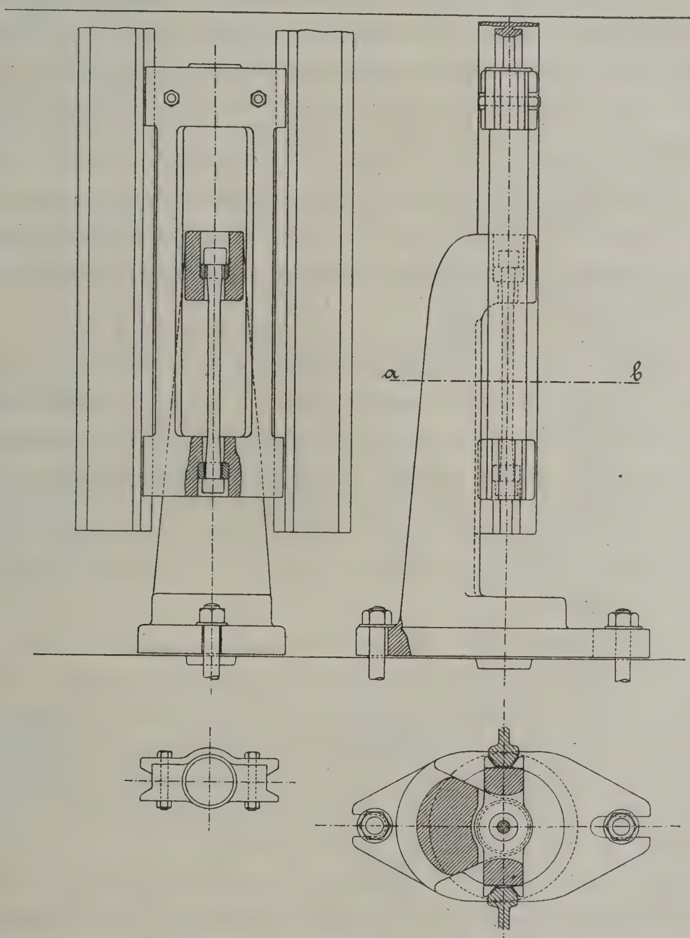

Fig. 2.

gives exceedingly correct results and was used in the tests given below.

After the above-described graduation of the monkey we proceded to the tests themselves, that is to say we placed the tensile-test samples in the apparatus.

The longitudinal dimension of the samples was that in use as the standard for cylindrical tensile-tests, but, on account of the largeness of the amount of work required to produce rupture, we have reduced the diameter at the smallest point. For a length of 110 m we reduce the diameter of the sample to about 10 mm, and for the calculation of the elongation we make use of the length of 100 mm. In this way, the samples have three diameters — that at the head about 25 mm, that at the ends of the part tested 15 mm, and that in the middle 10 mm. The length of the sample between the heads was about 240 mm. The sample was placed in the apparatus, and the spring was arranged below as described in the foregoing. In place of the triple spring we have adopted a single one, this being more delicate for the measurement of the strain. Finally the monkey was raised to a height of 3 m and allowed to fall. As a result of the fall the sample broke and the frame together with the monkey continued its movement, bearing on the spring and compressing it to a greater or less degree always in proportion to the kinetic energy remaining in the monkey after the rupture of the sample. It is evident that the work of the monkey absorbed by the triple spring at the first test (made without the sample), less the work absorbed by the single spring at the second test (made with the sample) is equal to the work done in the rupture.

All the other conditions are practically identical in the two cases; the friction against the guides is exactly the same, for the monkey runs, so to speak, through the same part of these; the losses of work in the deformation of the monkey and of the frame are equal in amount, and there is in fact only one new obstacle to the motion of the monkey, viz the test sample, and it alone diminishes the work absorbed by the spring.

The small spring is graduated like the large one, and its compression is indicated in the same manner as that of the latter.

It is possible at the same time to determine the elongation of the sample and percentage of contraction of the section. The test accordingly gives three values, viz:

1. the work done in rupture (the kinetic energy),
2. the elongation of the sample,
3. the contraction of the section.

We shall now give the results of the tests in figures. For the investigations we were supplied with three kinds of cast steel of different degrees of hardness, and a series of samples were prepared, some of which were subjected to the tensile test in the ordinary machine of Mohr and Federhaff. In this case samples were tested by the machine in order to serve as objects of comparison with others of the same dimensions which were ruptured by the impact, that is to say, the samples had a length of 110 mm and a diameter of 10 mm at the smallest point. At the same time diagrams were obtained in order to determine their coefficients.

The static tests have given the following results: (we cite the mean results of three tests of each sort.)

	Soft Cast-Steel	Hard Cast-Steel	Extra Hard Cast-Steel
Breaking Strain . . . . kgs.	3050	5240	6630
Elastic limit . . . . kgs.	2150	3050	3940
Elastic limit . . . . %	70	60	60
Ultimate tensile strength . . kgs. per sq. mm	39	67	88
Elongation . . . . %	31	30	8
Contraction . . . . %	63	43	23
Diagram coefficient . . . . %	90	90	90
$R + 2\alpha$	101	107	104
$R\alpha$	1209	1340	704

It will be convenient to note, that under "the diagram coefficient" is to be understood the value showing what proportion of the rectangle enclosing the diagram of rupture the exact surface of the latter takes up, which is then a measure of the work required to break the sample. The work is evidently equal to the product of the breaking strain multiplied by the total elongation between the heads of the sample and by the said coefficient. If the work be designated by T, the breaking strain by P, the whole elongation of the sample between its heads by Δl, and the coefficient by α, we find:

$$T = \alpha . P . \Delta l \quad .$$

whence we can determine P, since T, α, and Δl are known, so that

$$P = \frac{T}{\alpha . \Delta l}.$$

Let us now pass on to the results of the impact tests. (As many as 10 samples of each sort had been tested.)

	Soft Cast-Steel	Hard Cast-Steel	Extra Hard Cast-Steel
Height of fall of the monkey . . . . m	3	3	3
Total work accumulated in the monkey kgs. per m	101	101	101
Compression of the small spring after the rupture . . . . mm	37	40	56
Corresponding work (acccording to the spring graduation readings) . kgs. per m	12	14	28
Work required to cause rupture, kgs. per m	89	87	73
Elongation . . . . %	32	20	11
Contraction . . . . %	69	48	24
Total elongation between the heads . . mm	33	20·5	11·7
Breaking load according to the formula: $P = \frac{T}{\alpha \cdot \Delta l}$ . . . . kgs.	3040	4720	6930

All these results are grouped together in the following tables:

	Static Tests	Dynamic Tests
Soft Steel: Breaking load	3050	3040
Elongation	31%	32%
Contraction	63%	69%
Hard Steel: Breaking load	5240	4750
Elongation	20%	20%
Contraction	43%	48%
Extra Hard Steel: Breaking load	6630	6930
Elongation	8/%	11%
Contraction	23%	24%

In the examination of these tables it must be kept in view that the tests are not yet quite finished, and that the completed work will no doubt show results that are in better agreement with each other.

On the ground of these test results and in view of the considerations referred to above, I may be allowed to draw the following conclusions:

1. The impact bending test on notched bars is undoubtedly of great interest; it forms a good criterion of the brittleness of the material, and its application ought to be widely extended; but since it is not directly in harmony with the fundamental standard tensile tests, it only gives the kinetic strength of the material, and does not enable the numerical results obtained to be compared with those of the static tensile test.

2. The impact tensile test on standard samples is easily made by means of the Martens drop-weight machine; having by its aid determined the amount of work accumulated in the falling load before the rupture of the sample, by means of the carefully graduated springs, we can obtain the work of rupture exactly. At the same time we determine the elongations of the test sample (complete and relative for the length of 100 mm), and the contraction of Section III.

3. The results obtained by the impact tensile test give numerical values which agree with the results of the static test; the elongations and contractions are the same, and so also is the breaking strain. This latter may be determined from the work of rupture and from the total deformation of the sample, the coefficient of the rupture diagrams being taken as 90%.

4. In conformity with the foregoing, the impact tensile test not only supplements the static tensile test in giving the value of the kinetic strength of the material, but in certain cases can replace it in giving all the principal characteristic values of the properties of the material except that of the elastic limit, which can be determined as a fixed part of the breaking load.

The use of the impact tensile test may be recommended for the further reason that the cost of the apparatus with its accessories is less than that of the tensile-test machine, and all the imperfections of the installations of the drop-test machine are of a harmless kind, since allowance can be made for them by the aid of the springs mentioned above.

5. The considerations set forth above allow us to give expression to the wish, that the impact tensile test may come into use in the mechanical laboratories side by side with the impact bending test, and that the experiences of the laboratories may enable a definite judgement to be formed as to the utility of this testing method, which has been studied by Prof. Martens also, but which up till now has not been taken up to the extent that it deserves.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

VIII2

ON THE UNIFORM NOMENCLATURE OF IRON AND STEEL.

Report of Committee 24. Presented by Prof. **Henry M. Howe**, Chairman, New York, and Prof. **Albert Sauveur**, Secretary, Cambridge, Mass.

The Committee appointed for the solution of the above problem consisted of the following members:

Chairman: *Howe H. M.*, Metallurgist, Professor Metallurgy, Columbia University, New-York.

Vice-Chairman: *Lévy L.*, Ingénieur en chef de Mines, Directeur de la Cie. des Forges de Chatillon, Commentry et Neuves-Maisons, Paris.

Tschernoff D., Professeur, Conseiller d'Etat actuel, Saint Pétersbourg.

Secretary: *Sauveur Alb.*, Professor Harvard University, Cambridge, Mass.

Members:

Van Drunen James, Ingénieur, Professeur à l'Université de Bruxelles.

Tuxen H. L., H., Oberstleutnant, Kopenhagen.

Wedding H., Dr., Geheimrat, Professor, Berlin (†).

Brauns H., Kommerzienrat, Dortmund.

Martin Ed. G., The Hill, Abergavenny, South Wales.

Harbord F. W., F. J. C., Assoc. R S. M., Consulting Metallurgist and Analytical Chemist, London.

Stead J. E., F. R. S., Laboratory and Assay Office, Middlesborough.

Le Chatelier H., Inspecteur général des Mines, Membre de l'Institut, Paris.

Pourcel A., Ing. civil des Mines, Paris.

Koning K. F., Oberingenieur im Marineministerium, Haag.

Verole Pietro, Ing. en chef des Chemins de l'Etat, Rome.

Baalsrud A., Abteilungsingenieur d. königl. norweg. Wegebau-Directorats, Christiania.

Dormus A. R. v., Inspector der k. k. Nordbahn, Wien.

Sailler A., Oberingenieur a. D., Wien.

Bureau des forges, St. Pétersbourg.

Belelubsky N., Dr., Professeur ém., Directeur du Labor. méc. à l'Institut Impér. des voies de comm., St. Pétersbourg.

Jossa N,, Directeur du dép. des mines, Ministère des domaines, St. Pétersbourg.

Korobkoff M., Général-major du Génie militaire, St. Pétersbourg.

Smirnoff S., Directeur de l'usine de Pontiloff, St. Pétersbourg.

Campbell H. H., Metallurgical Engineer The Pennsylvania Steel Company, Philadelphia, Pa.

Campbell W., Adjunct Professor of Metallography, Columbia University, New York, N. Y.

The first report of this committee was presented at the Congress held in Brussels in September 1906. It consisted of four parts: 1. A polyglot giving the names of the chiefs classes of iron and steel in English, French, German, Swedish and Danish; 2. English definitions of the principal classes of iron and steel; 3. a glossary of special sizes and shapes of iron and steel and 4. a note on the boundary between steel and cast iron.

The report was accepted by the Congress and your Committee was instructed to continue their work. It was also suggested that Italian and Spanish equivalents be included in the polyglot and that opinions be secured as to the work of the Committee from the following societies:

Association des Ingénieurs sortis de l'Ecole des Mines de Liège.

The Iron and Steel Institute.

Le Comité des Forges de France.

The American Institute of Mining Engineers.

Verein Deutscher Hüttenleute.

Jern Kontoret.

Editors of the Technolexicon.

Your committee has complied as far as possible with these instructions in the drawing of the present report, which will be found divided into the following parts:

1. A polyglot giving the names in English, French, Italian, Spanish, German, Swedish, Danish and Dutch of the chief classes of iron and steel.

2. English definitions of the principal classes of iron and steel and of the microscopical constituents of these metals.

3. A glossary of special sizes and shapes of Iron and Steel.

4. Opinions of Societies.

I. Polyglot, in English, French, Italian, Spanish, German, Swedish, Danish and Dutch, of the chief classes of iron and steel.

This list is not intended to be complete, but rather to include only those varieties which are of interest to the Association.

The Italian equivalents added to the present polyglot were furnished to the Iron and Steel Institute[1]) by Mr. F. B. Rognetta (Rome), by Dr. V. Sevieri (Piombino), by the Società Siderurgica di Savona, and by Mr. Peter A. Jackson (Stabilimento Armstrong, Pozzuoli). The Spanish equivalents were kindly furnished by Colonel Cubillo (Trubia).

Many additions have been made to the lists of German, Swedish, Danish and Dutch equivalents. These were made at the request of the Iron and Steel Institute[2]) by the editor of „Stahl und Eisen", by Professor J. H. Hannover (Copenhagen), by J. L. Terneden (Berlin), by Mr. Paul Zetzsche (Libau) and by Professor Wedding. A few names have also been corrected. Your committee believes this polyglot now to be sufficiently complete and to contain but few orthographic or other errors.

II. Definitions.

Alloy Cast Irons, those which owe their properties chiefly to the presence of an element (or elements) other than carbon.

Alloy Steels, those which owe their properties chiefly to the presence of an element (or elements) other than carbon.

Basic Pig Iron. In America, pig iron containing so little silicon and sulphur that it is suited for easy conversion into steel

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1) Journal Iron and Steel Institute. September 1907.

2) Loc. cit.

by the basic open-hearth process. It is restricted to pig iron containing not more than 1·00 per cent of silicon.

In England and on the Continent, pig iron containing so little silicon and sulphur that it can be converted into steel easily by the basic Bessemer or basic open-hearth process. It generally contains 1·00 per cent. or more of manganese and 1·50 to 3·00 per cent of phosphorus, silicon averaging not more than 1·00 per cent and sulphur 0·10 per cent. Other varietes treated by the basic Bessemer or basic open hearth process are not regarded as basic pig, but simply as phosphoric pig.[1])

Bessemer Pig Iron, that which contains so little phosphorus and sulphur that it can be used by itself for conversion into steel by the original or acid Bessemer process. In America this term is restricted to pig iron containing not more than 0·10 per cent of phosphorus.

In England this term is restricted to pig iron containing not more than 0·06 per cent of phosphorus or sulphur.[2])

Blown metal, the red short metal made by purifying pig iron in the Bessemer converter without subsequently removing the oxygen which it absorbs during that purification.

Bessemer Steel, steel made by the Bessemer process, whether its carbon content is high, low or intermediate.

Blister Steel, steel made by carburizing wrought iron by heating it in contact with carbonaceous matter. It might also be made by so carburizing a low-carbon steel. Much of the blister steel of commerce is made by cementing Swedish wrought iron in charcoal.

Certain comments, *e. g.* that on the definition of "Blister Steel", that it would facilitate fraud, are based on error as to the true function of definition, to express briefly the meaning of a word, and to set up the limits which separate the thing described

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[1]) This paragraph was inserted at the suggestion of Mr. C. H. Ridsdale. That this is the accepted meaning of basic pig iron in England is also stated by Mr. J. E. Stead. Professor H. Wedding likewise wrote:

Basic pig iron in America is quite different from that in Germany. In Germany basic pig iron and Thomas pig iron (Thomasroheisen) have the same signification. In America the therm is restricted to pig iron containing not more than 1 per cent of silicon, without regard to the percentage of phosphorus, but the German (Thomasroheisen) must contain more than $1^1/_2$ per cent of phosphorus, and in reality contains less than 0·5 per cent of silicon.

[2]) This paragraph has been inserted at the suggestion of Mr. C. H. Ridsdale.

from those with which it is likely to be confused. That protection against fraud is not to be demanded of definitions is seen clearly on considering the definition in common use. Would it be wise, even if it vere possible, that the definition of "Horse" should exclude undesirable horses, *e. g.* the blind, lame, vicious and diseased? Are they not horses, bad ones, but still horses?

In fact no one of our definitions should or would offer the least obstacle to fraud. It would not be proper to define blister steel in such a way as to exclude that made from puddled iron or from phosphoric or sulphurous iron whether puddled or made in the charcoal hearth. But even if one should go to that length, or the still more absurd length of defining blister steel as "Swedish bar iron subjected to the process of cementation in charcoal" and thereby excluding all French, German and American blister steel, that would not prevent fraud. The unscrupulous could make Swedish bar iron rich in phosphorus or sulphur; or convert Swedish muck bar; or offer improperly or insufficiently cemented steel; or scraps and crop ends of such steel. The proper protection against fraud lies either in buying from those whose character is in itself a guarantee, or else in relying on specifications incorporated in the contract of purchase.

But though the proposition to restrict the meaning of "Blister steel" so as to exclude all but that made from Swedish bar iron, or otherwise to exclude any steel which has the carbon-content of blister steel and is made by cementing any wrought iron, pure or impure, in any carburizing material, solid, liquid, or gaseous seems to us hardly open to discussion, yet the further question whether the presence of blisters is essential to blister steel is one on which opinions may reasonably differ. To us it seems that, just as "cast iron" properly includes all very highly carburized iron, *e. g.* that made by cementing wrought iron until it contains 4% of carbon, in spite of the fact that such material may never have been cast, so Bessemer steel which has been carburized by the cementation process ought to be called "blister steel" in spite of its freedom from blisters. In other words, in our opinion the essential quality of cast iron is its composition and not its being cast, and the essential quality of blister steel is its composition caused by cementation and not its blisters. On this point the opinion of members is requested.

We add to our definition the assertion that much of the blister steel of commerce is made by cementing Swedish wrought iron in charcoal.

Cast Iron. Generally, iron containing so much carbon or its equivalent that it is not usefully malleable at any temperature. Specifically, cast iron in the form of casting other than pigs, or remelted cast iron suitable for casting into such castings, as distinguished from pig iron, *i. e.* cast iron in pigs, etc. (See Pig Iron.) For instance, cast iron pigs, *i. e.* pig iron, like lead in pigs, *i. e.* pig lead, is remelted and cast into castings, such as columns, locks, gears, etc., of special shape suited to their special purpose; these are specifically called „cast iron", and this is the usual restricted meaning of "cast iron" in trade language.

The Committee recommends drawing the line between cast iron and steel at 2·20 per cent carbon for the reason that this appears from the results of Carpenter and Keeling to be the critical percentage of carbon corresponding to the point "a" in the diagrams of Roberts-Austen and Roozeboom. As to the signification of this critical point the Committee is not prepared to express an opinion[1]).

Cast Steel, in the iron trade means "crucible steel". Obsolescent and undesirable because it might easily be understood to include other steels which have been cast[2]).

Cemented Steel, the same as blister steel.

Charcoal Hearth Cast Iron, cast iron which has had its silicon and usually its phosphorus removed in the charcoal hearth, but still contains so much carbon as to be distinctly cast iron.

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[1]) Professor Wedding reports that in Germany every metallic product ot the blast furnace is called pig iron or cast iron, and appears to dissent from drawing any line between cast iron and steel. Mr. Brinell thinks that 2,20 per cent of carbon is a rather high limit for practical purposes.

Mr. J. E. Stead thinks it "inadvisable to place the dividing line at such a low percentage as 2,2 per cent".

[2]) This modification of the definition of cast steel as it appeared in our first report is based on one suggested by Mr. C. H. Ridsdale, who further argues that the meaning of the term should be so restricted as to apply only to "steel cast into shape as contra-distinct to rolled or forged, etc.". While this would be a desirable restriction it would be contrary to the generally accepted meaning of the terms and the obvious duty of this Committee is evidently to record and describe as faitfully as possible the current significations attached to the various terms rather than to attempt an arbitrary improvement of the nomenclature.

Converted Steel, the same as blister steel.

Crucible Steel, steel made by the crucible process, whether its carbon content is high, low or intermediate.

Gray Pig Iron and Gray Cast Iron, pig iron and cast iron in the fracture of which the iron itself is nearly or quite concealed by graphite, so that the fracture has the gray colour of graphite.

Hematite Pig Iron, originally pig iron made from the hematite ores of England, which happen to be so free from phosphorus and sulphur that the pig iron made from them can be used by itself for the acid Bessemer process. By association it has come to mean any pig iron thus relatively free from phosphorus and sulphur. The term is not used in America, and is undesirable.

Hot Metal or Direct Metal, the molten cast iron from the blast furnace before it has been allowed to solidify. The term is generally applied to molten metal taken direct from the blast furnaces to the steel-making plant.

Ingot Iron, steel cast into an initially malleable mass and containing so little carbon or its equivalent that it does not harden greatly when cooled suddenly and completely from a red heat. The word is rarely used in English, but "mild steel" or "low carbon steel" or "soft steel" is generally used in its place. In America the line between soft steel and half-hard steel is usually drawn at a carbon content of about 0,20 per cent.[1])

Ingot steel, steel cast into an initially malleable mass and containing so much carbon or its equivalent that it hardens greatly on sudden cooling. The word is rarely used in English, but "hard steel", "high-carbon steel" or "half-hard steel" are used in its place.

Malleable Castings, castings of malleable cast iron, which see.

Malleable Cast Iron, iron which when first made is cast in the condition of cast iron, and is made malleable by subsequent treatment without fusion.

Although the English name of this variety suggests that it is cast iron, it is not truly a variety of cast iron, but rather forms an independent species of iron, because it lacks the essential property of cast iron, *viz.* its extreme brittleness. Though the term "malleable castings" is very common, the term "malleable

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[1]) Mr. C. H. Ridsdale advices adding after the last word: "in Great-Britain at a carbon content of from 0·10 per cent to 0·15 per cent."

cast iron" is very rarely used. The common, but inexcusable term we regret to say is "malleable," pronounced "mallable", used as a substantive. Those with some respect for their mother tongue, if asked of what material a malleable casting was composed, would generally use a circumlocution.

Malleable Iron, the same as wrought iron. Used in Great-Britain, but not in the United States, except carelessly as meaning "malleable cast iron" (vulgar "malleable").

Malleable Pig Iron, an American trade name for the pig iron suitable for converting into malleable castings through the process of melting, treating when molten, casting in a brittle state, and then making malleable without remelting. The term should be used with care to avoid confusion. This material is also called in trade in America "malleable iron" but this use should be avoided, because "malleable iron" has the older and (in Great-Britain) firmly established meaning of "wrought iron".

Mottled Pig Iron and Mottled Cast Iron, pig iron and cast iron the structure of which is mottled, with white parts in which no graphite is seen, and grey parts in which graphite is seen.

Open Hearth Steel, steel made by the open hearth process, whether its carbon content is high, low or intermediate.

Pig Iron, cast iron which has been cast into pigs direct from the blast furnace. This name is also applied loosely to molten cast iron which is about to be so cast into pigs or is in a condition in which it could readily be cast into pigs.

Plate Iron, a name sometimes applied in Great-Britain to refined cast iron.

Puddled Iron, wrought iron made by the puddling process.

Puddled Steel, steel made by the puddling process, and necessarily slag-bearing. (See Weld Steel.) It differs from wrought iron only in being richer in carbon. It differs from most other steels in containing much cinder.

Refined Cast Iron, cast iron which has had most of its silicon removed in the refinery furnace, but still contains so much carbon as to be distinctly cast iron.

Shear Steel, steel, usually in the form of bars, made from blister steel by shearing it into short lengths, piling and welding

these by rolling or hammering them at a welding heat. If this process of shearing, piling, etc., is repeated, the product is called "double shear steel".

Steel, iron which is usefully malleable at least in some one range of temperature, and in addition is either (a) cast into an initially malleable mass; or (b) is capable of hardening greatly by sudden cooling: or (c) is both so cast and so capable of hardening. Variety A includes also molten iron which if cast would be malleable, as do its two sub-varieties, "ingot-iron" and "ingot steel". (Tungsten steel is malleable only when red-hot.)[1]

Steel Cast, (adjective, consisting of solid Bessemer, open hearth, crucible or other slaglees steel, and neither forged nor rolled: applied to steel castings. For instance, a "steel cast" gun is a gun which is a steel casting, *i. e.*, which has been neither forged nor rolled. To call it a "cast steel" gun would imply that it was made of crucible steel, to which the term "cast steel" is restricted.

Steel Castings, unforged and unrolled castings made of Bessemer, open hearth, crucible or any other steel. Ingots and pigs are in a sense castings; the term "steel castings" is used in a more restricted sense, excluding ingots and pigs and including only specially shaped castings, such as are generally used without forging or rolling. They may, however, later be forged, *e. g.*, under the drop press, when they cease to be "castings" and become "drop forgings", or if only part is forged then they are partly forgings and partly castings.

Washed Metal, cast iron from which most of the silicon and phosphorus have been removed by the rich ferruginous slags of the Bell-Krupp process or its equivalent without removing much of the carbon, so that it still contains enough carbon to be classed

[1]) Mr. Alexander Pourcel writes that he agrees with the classification of iron and steel presented by Mr. Greiner at the meeting of the Association held in Paris in 1900. "Irons are", Mr. Greiner said, "distinguished from steels simply by the process of manufacture. Thus, all malleable cast metal is steel; all malleable metal not cast is wrought iron. There are to be distinguished 1. pig iron, cast metal non-malleable: 2. wrought iron, malleable metal not cast; and 3. steel, cast and malleable metal." A serious, if not fatal objection to this classification is that, according to it, what has hitherto been called blister steel becomes wrought iron.

as cast iron. The name "washed metal" is extended to cover this product even if its carbon is somewhat below the proper limit for cast iron.

Weld Iron, the same as wrought iron. Obsolescent and needless.

Weld Steel, iron containing sufficient carbon to be capable of hardening greatly by sudden cooling, and in addition slag-bearing because made by welding together pasty particles of metal in a bath of slag, as in puddling, and not later freed from that slag by melting. The term is rarely used.

White Pig Iron, and White Cast Iron, pig iron and cast iron in the fracture of which little or no graphite is visible, so that their fracture is silvery and white.

Wrought Iron, slag-bearing, malleable iron, which does not harden materially when suddenly cooled.

Wrought Steel, the same as weld steel. Rarely used.

Definitions of the Microscopical Constituents (Metarals) of Iron and Steel.

These definitions are based on the known and usually indisputable properties of the several constituents, and not on their nature or constitution, which are still in dispute and likely to remain so for sometime, because of the complexity of their genesis and the imperfection and obscurity of our evidence. But we supplement the definitions with a brief statement of the more m portant present opinions as to the constitution of thes constituents.

In this connection the chairman of this committee suggests the word "metaral", the analogue of "mineral", as the equivalent of the bulky term "microscopical constituents". It is more accurate than "microscopical constituent", because these substances are often far from microscopical, *e. g.* the graphite of pig iron and the primary cementite of ferro-manganese. Moreover "constituent" seems vague. Occluded gas and dissolved iron oxide are surely constituents but hardly "metarals", just as the carbonic acid dissolved in mineral water, though a constituent, is not itself a distinct mineral when so dissolved.

Preliminary Statement. Pure and commercial carbon steels consist normally when in region IV (see fig. I) of (1) Austenite, and when in region IX of (2) ferrite and (3) cementite, partly (and in case of eutectoid steel wholly) intermixed mechanically as (4) pearlite. In changing in cooling from austenite into ferrite and cementite the metal passes successively through the stages of (5) Martensite, (6) Troostite and (7) Sorbite, and it passes back in

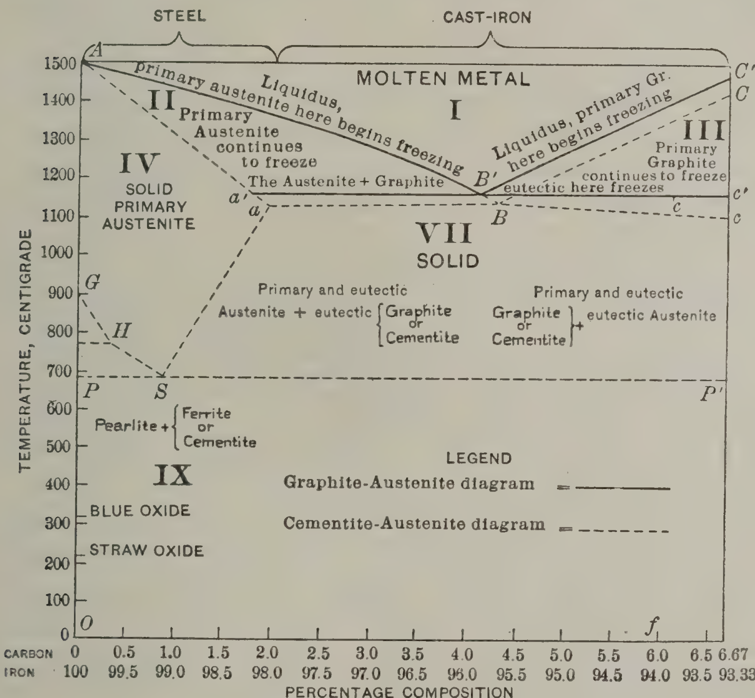

Fig. 1.

the reverse order through those stages in changing back from ferrite and cementite into austenite on heating[1]). Though stages 5, 6 and 7 thus seem to have no region in which they exist normally and in equilibrium, but at most a mathematical line, they may be

[1]) Other transition constituents, *e. g.*, Osmondite and Troosto-sorbite (stages intermediate between troostite and sorbite), have been described by some writers, but the Committee believes that these terms, which at most represent constituents of only hypothetical existence, are neither needed nor used enough to justify giving them a place in this list of definitions.

preserved through lag by sudden cooling, and so may austenite under favorable conditions. Moreover, the presence of considerable quantities of carbon, manganese, and nickel both lower the boundaries between regions IV and IX, and increase the lag, in both ways facilitating the retention of austenite and martensite in the cold, in extreme cases lowering these boundaries to below the atmospheric temperature, and perhaps expanding the mathematical line at which martensite is normal into a region covering many degrees of temperature.

Austenite: A solid solution of carbon (or of an iron carbide) in gamma iron, stable above the critical range.[1]) At all temperatures, above the critical range all iron-carbon alloys and, therefore, all varieties of carbon-steel and cast iron consist of austenite, often mixed, in the case of highly carburized alloys, with graphite.

During slow cooling through the critical range austenite is converted into pearlite, a mechanical mixture in definite proportions of ferrite and cementite, further mixed with free ferrite or free cementite, according to whether the steel is hypo- or hyper-entectoid. Austenite can be retained in the cold by cooling the metal from above its critical range so rapidly that the transformation of some of that constituent is prevented. But this retention is possible only in the presence of a considerable quantity of carbon, which acts as a brake in preventing the transformation, or of some other element or elements like manganese and nickel, exercising a similar brake action. In the presence of large proportions of such elements austenite may be retained in the cold even after slow cooling: thus steel containing some 25 per cent of nickel, is austenitic, even when cooled slowly.

Austenite which has been retained in the cold by the presence of a quantity of carbon, manganese and nickel, but little more than barely sufficient, is liable to change into martensite on undergoing shock or deformations. Austenite is habitually considerably softer than martensite and but slightly harder than ferrite (Osmond); it is non-magnetic and possesses a very high electrical resistance.

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[1]) By critical range is meant in these definitions the range of temperature between the three thermal critical points A3, A2 and AI.

In specimens properly prepared for microscopical examination, austenite remains light and fills up the spaces between the darker colored needle-like crystals of martensite generally accompanying it.

Martensite. A transition constituent corresponding to the first stage in the transformation of austenite, as the metal enters its critical range. On slow cooling through the entire critical range, martensite is converted into pearlite (ferrite + cementite).

To retain martensite in the cold, the rate of cooling must be slow enough to let it form, but not so slow as to let it in turn decompose. These conditions are generally fulfilled in the commercial operation by which steel is hardened. This consists in cooling the metal quickly from a temperature above its critical range by plunging it in cold water or in some other suitable medium. Martensite, therefore, is the usual constituent of hardened carbon steel. It is generally accompanied by cementite in high carbon alloys, but by ferrite in very low carbon steel. Troostite, the next stage in the transformation of austenite is also frequently present in commercially hardened steel.

Martensite is, next to cementite, the hardest constituent of iron-carbon alloys. It is very magnetic and appears to contain about half of its carbon as hardening carbon.

In specimens properly prepared for microscopical examination, martensite is found to occur as irregular and ragged sheets, which in the section appear as needles generally parallel to the three sides of a triangle, and frequently crossing each other. By the usual methods of etching, martensite is colored darker than austenite, cementite and ferrite, but not as dark as troostite, but after very careful preparation it may be white. While metallurgists do not agree in regard to the exact nature of martensite, it is generally admitted that it contains beta iron to which it owes its hardness, and alpha iron to which it owes its magnetic properties. But there is considerable difference of opinion in regard to the relation which the carbon bears to the iron. Some believe that martensite is essentially a solid solution, perhaps abnormal in nature, of carbon (or of an iron carbide) in beta iron (Osmond), while others regard it as essentially a solution of carbon in alpha iron, denying indeed the existence of beta iron (Le Chatelier).

Troostite. A transition constituent corresponding to the second stage in the transformation of austenite. It forms during

relatively slow cooling through the upper part of the critical range. On slow cooling through the entire critical range, troostite is converted into pearlite (ferrite + cementite).

The intermediate rapidity of cooling which allows the transformation to reach, but not to pass the troostite stage, and thus preserves troostite in the cold, is given by qnenching either (1) in oil or hot water from above the critical range, or (2) in cold water from within that range, or (3) in case of the relatively slowly cooling central parts of large objects or objects protected by any thin coating, by quenching from above that range in cold water. Moreover cold austenite and martensite change into troostite on very slight reheating (to 200 or 275^0 Cent.) as in tempering.

For given carbon-content troostite is softer than martensite, but harder than sorbite and pearlite. It probably contains a considerable amount of hardening carbon.

In specimens properly prepared for microscopical examination, troostite occurs in irregular, granular, almost amorphous areas, colored much darker than the accompanying martensite by the usual etching methods.

Metallurgists do not agree as to the nature of troostite. Some believe that it is a solid solution of carbon (or of an iron carbide) in iron (probably alpha iron), while in view of its specific volume and its specific resistance being identical with those of pearlite, others believe that it is simply a colloid or microscopically irresoluble form of pearlite which may or may not be mixed with equally undetectable ferrite, cementite, austenite or martensite.

Sorbite. A transition constituent corresponding to the third stage in the transformation of austenite.

The intermediate rapidity of cooling which allows the transformation to reach, but not to pass the sorbite stage and thus preserves sorbite in the cold is given by quenching in cold water from the lower part of the critical range, or in oil from above that range, or by air cooling very thin pieces from above the critical range, or finally by reheating (tempering) hardened steel to a little above 500 degrees cent.

Sorbite is softer than troostite, but harder than pearlite. It probably contains some hardening carbon.

In specimens properly prepared for microscopical examination sorbite occurs as an ill defined, almost amorphous constituent,

colored lighter than troostite, but darker than pearlite by the usual methods of etching.

Sorbite is generally thought to be essentially irresoluble pearlite i. e. a mechanical mixture of particles of ferrite and cementitel which have been denied the necessary time for their segregation into the well defined parallel plates characteristic of the structure of pearlite. In hypo-eutectoid steel, sorbite frequently contains a larger proportion of ferrite than pearlite.

Pearlite, the "eutectoid", a mechanical mixture of six parts of ferrite with one of cementite, stable below the critical range It contains almost 0·90 per cent of carbon. It is the final stage in the transformation of austenite

From the fact that pearlite is the normal condition at all temperatures below the critical range it follows that cold steel consists of pearlite whenever the cooling from the lower limit of the critical range has been slow enough to allow the other and unstable constituents to be transformed into pearlite. Thus it is the normal constituent of steel when annealed.

It is accompanied by free or massive ferrite in hypo-eutectoid steel (steel containing less than some 0·90 per cent carbon) and by free or massive cementite in hyper-eutectoid steel (steel containing more than some 0·90 per cent carbon).

It is softer than sorbite but considerably harder than ferrite.

It is nearly, if not quite free from hardening carbon.

In specimens properly prepared for microscopical examination pearlite occurs in groups of very fine, but clearly defined parallel plates or lamellas, alternately of ferrite and cementite. If the magnification is sufficient to resolve pearlite into its constituents, ferrite and cementite, the ferrite looks black and the cementite white. When etched by the usual methods, pearlite is darker than ferrite and cementite, but lighter than sorbite.

Cementite. The carbide of iron Fe_3C. It occurs chiefly either (1) as "primary" cementite, forming large plates in white cast iron, spiegeleisen, etc.; or (2) as a component of pearlite (q. v.); or (3) as "free", "excess" or "massive" cementite (these terms are identical in meaning) in white cast iron and in slowly cooled hyper-eutectoid and especially "cemented" steel, whence its name.

Gray cast iron, in spite of its large carbon content, often lacks "free" cementite, because so much of its carbon has instead formed graphite, on account of slow cooling or of the presence of silicon or its equivalent.

In alloys containing certain other elements, such as manganese, in relatively large amount, instead of the single carbide $Fe_3 C$, double and possibly trible carbides are formed to which the name of cementite is likewise given.

Cementite is the hardest constituent of iron-carbon alloys.

In specimens of hyper-eutectoid steel properly prepared for microscopical examination, the cementite generally occurs either as a fine network surrounding meshes of pearlite, or in streaks detached from the network and crossing the pearlite meshes. When etched by the usual methods cementite remains bright and structureless.

Ferrite. Alpha iron holding in solution in the case of commercial grades of iron and steel, small and varying amounts of silicon, manganese, phosphorus and of some other rarer elements, but not more than 0·05 percent of carbon if any.

In the complete or nearly complete absence of carbon the metal consists exclusively of ferrite regardless of the treatment to which it has been subjected. In the slow cooling of hypo-eutectoid steels and graphitic cast iron with less than about 0·90 of combined carbon, the iron present in excess of the eutectoid ratio of about 99·10 parts of iron to 0·90 parts of combined carbon turns, in passing from Ar 3 to Ar 1, into "free" ferrite. In the slow cooling of all carbon steels and cast iron, ferrite forms, as one member of the eutectoid "pearlite", in passing the recalesence point, Arl. Even in the cast irons richest in carbon, ferrite forms on long high heating, by the splitting up of cementite with formation of temper graphite, $Fe_3 C = 3 Fe + Gr$.

Ferrite is the softest constituent of iron-carbon alloys. In specimens properly prepared for microscopical examination ferrite occurs in polyhedric crystalline grains or in case the carbon exceeds some 0·40 per cent as a network surrounding meshes of pearlite. By the usual methods of superficial etching ferrite remains brighter than pearlite, but on deeper etching some of the polyhedric grains are colored more or less deeply while others remain bright.

III. Glossary of special sizes, shapes and conditions of iron and steel.

English	French	German	Swedish	Spanish	Italian
Bar Iron, wrought iron in the form of bars, rods, etc.		Stabeisen Stangen-eisen		Hierros laminados	Ferro in verghe
Muck Bar, the rough bars usually 1 inch thick and about 4 inches wide, made by the first rolling of a ball of puddled iron.	Loupe, Lopin, Ébauché de puddlage, Fer brut.	Rohzaggel	no equivalent	Planchuela basta	Spuntature
Merchant Bar, wrought iron in the form of merchantable bars or rods made by shearing muck bar into short lengths, piling it and rolling or forging it at a welding heat.		Handels-eisen Merkantil-eisen		Hierros comerciales	Verghe mercantili (barre da commercio
Bloom 1. A large bar, drawn from an ingot or similar mass, for further manufacture. 2. A rough bar of wrought iron drawn from a Catalan or bloomary ball for further manufacture.	Bloom	Luppe Platte Wolf		Tocho	Massello
Billett A small bar drawn from a pile, bloom or ingot for further manufacture. The committee recommends that the line between blooms and billets be drawn at the size of 5 inches square[1], as representing common custom.	Billette	Packet Knüppel		Billet	Verghe grezze (billette)
Slab. A flat piece or plate, with its largest surfaces plane drawn or sheared from an ingot or like mass for further treatment.		Platine		Tocho para chapa	Picolo massello (piattine, placche)

*) Pourcel suggests 45 mm as a dividing line. — Brinell recommends 6″ square.

IV. Opinions of Societies.

In accordance with the suggestion of the council the secretary wrote in December, 1907 to the following societies, requesting them that the report of the Committee be considered and discussed at some of their meetings with a view of securing the opinions and criticisms of their respective members:

Association des Ingénieurs sortis de l'Ecole des Mines de Liège;
Comité des Forges de France;
American Institute of Mining Engineers;
Verein Deutscher Hüttenleute;
Jern Kontoret.

Neither the Iron and Steel Institute nor the editors of the Technolexicon were included in this request, because the former society had already discussed our report, while the work of the Technolexicon had been abandoned and the board dissolved.

Of the five associations addressed only one, the American Institute of Mining Engineers, replied to the secretary's letter. The secretary of that society called our attention to the well known fact that it is not permitted by its rules to pronounce a formal opinion upon any proposition presented to them, except so far as to recommend the use of a given nomenclature by its own members in contributions to its transactions.

But it printed our report together with some remarks in discussions.[1])

Our report was printed by the Iron and Steel Institute[2]) also, and discussed at some length by several of its members. But the Iron and Steel Institute, also failed, and for similar reasons, to express any formal opinion as to its merits.

The individual opinions expressed in the course of these discussions have been carefully considered by the Committee and it will be found that the equivalents of some of the suggestions made have been incorporated in the present report. In a few instances it has seemed expedient to explain why the other suggestions were not followed.

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[1]) Bi-monthly Bulletin-American Institute of Mining Engineers, Mar. 1908, pp. 227—237, and July, 1908, pp. 615—620.

[2]) "Journal of the Iron and Steel Institute" September 1907, No III for 1907.

I

En[g]	Dutch
Cast	Gietyzer (ruwyzer)
White c or pi	witgietyzer (witruwyzer)
Gray c or pi	Grauw gietyzer
Mottled or pi	wit korreliggietyzer
Pig iron gray, mo	Ruwyzer (gemeleerd)
Hot m direct	Ruwyzer cerste gieting
Basic c or pig	Thomas ruwyzer
Hematite or pig	Haematitruwyzer
Malleable	Smeedbaargietyzer
Washed	Ontphospherd gietyzer
Refined c	Gezuiverd gietyzer
Charcoal cast	Houtskolen gietyzer
Alloy ca	Special gietyzer
Malleable	Smeedbare gieting

[Ita]lian	Spanish	
iaio	Acero	
di ferro (acciaio lce)	Hierro fundido	
d'acciaio, emi-duro	Acero fundido	
s		
Bessemer	Acero Bessemer	B B
Martin	Acero de Solera	Fla Fla
crogiuolo	Acero de crisoles	
o fuso	Acero fundido	
acciaio ato	Piezas de acero colado	
saldato fucinato	Acero Soldado	S
s		
ementato crogiulo rburazione ementato	Acero cementado	
amascato saldato)	—	
udellato	Acero Pudelado	
acciaii speciali)	Aleaciones de Acero	
icinato aldato	Hierro forjado Hierro soldado	Sc
idellato	Hierro pudelado	
	—	I

ng a tenacity greater than 50 kg per sq
. mm should be called Schweißstahl and

Names				Names			
English	French	Italian	Spanish	German	Swedish	Danish	Dutch
Species				**Species**			
Cast iron	Fonte	Ghisa	Fundición de hierro	Roheisen if not remelted, Gußeisen if remelted	Tackjern Gjutjern	Raajern naar detikke er omsmeltet eller Stöbejern	Gietyzer (ruwyzer)
Varieties				**Varieties**			
White cast iron or pig iron	Fonte blanche	Ghisa bianca in pani, Ghisa bianca	Lingote de hierro blanco y fundición de hierro blanco	Weißes Roheisen	Hvitt tackjern	Hvidtjern	witgietyzer (witruwyzer)
Gray cast iron or pig iron	Fonte grise	Ghisa grigia	Lingote de hierro gris y fundición de hierro gris	Graues Roheisen	Grått tackjern	Graatjern Graat Raajern	Grauw gietyzer
Mottled cast iron or pig iron	Fonte truitée	Ghisa trotata	Lingote de hierro truchado y fundición de hierro truchado	Halbiertes Roheisen	Hagelstatt or Halfhwitt or halfgrått tackjern	Spragletjern	wit korreliggietyzer
Pig iron (white, gray, mottled, etc.)	Gueuses de fonte ou fonte en gueuse	Ghisa	Lingote de hierro	Gußeisen Roheisen (in Masseln oder Gänsen), Gußeisen (weiß, grau, halbiert)	Tackjern	Pigjern or Raajern	Ruwyzer (gemeleerd)
Hot metal, or direct metal	Fonte de première fusion?	Ghisa da prima fusione liquida	Metal caliente ó metal directo	Remeisen Roheisen, Gußeisen erster Schmelzung	Tackjern direct gjutet från Masugnen	Smeltet Raajern	Ruwyzer cerste gieting
Basic cast iron or pig iron	—	Ghisa basica in pani	Lingote de hierro básico	Thomasroheisen	—	Thomas Raajern	Thomas ruwyzer
Hematite cast iron or pig iron	—	Ghisa ematite in pani	Lingote de hierro hematites	Hämatitroheisen	—	Haematit Raajern	Haematitruwyzer
Malleable pig iron	—	Ghisa per affinazione	Lingote de hierro para fundición maleable	Schmiedbares Gußeisen	—	Hammerbart-Stöbejern	Smeedbaargietyzer
Washed metal	Fonte épurée	Metallo defosforato	Fundición de hierro refinada ó lavada	Entphosphortes Roheisen	Tvättad	Affosforet Raajern	Ontphospherd gietyzer
Refined cast iron	Fonte mazée	Ghisa affinata	Fundición de hierro refinada ó depurada	Geßeintes Eisen	Raffineradtjern	Raajern til Hardfriskning	Gezuiverd gietyzer
Charcoal hearth cast iron	Fonte mazée	Ghisa al carbone di legna	Fundición refinada al carbón vegetal, en fuego de afinería	Herdfrischeisen Holzkohlen Herdfrisch-Roheisen	Tackjern för härdfärskning	Raffineret Raajern	Houtskolen gietyzer
Alloy cast iron	Fontes spéciales	Lega di ghise (ghise speciali)	Aleaciones de hierro colado	Sondergußeisen	Special tackjern	Special Raajern	Special gietyzer
Species				**Species**			
Malleable castings	Fonte malléable	Pezzi fusi (getti) di ghisa malleabile	Piezas de fundición de hierro maleable	Schmiedbares Gußeisen or schmiedbarer Guß	Aduceradt jern	Hammerbart Stöbejern, Hammerbart Stöbegods	Smeedbare gieting

II

Names				Names			
English	French	Italian	Spanish	German	Swedish	Danish	Dutch
Species				**Species**			
Steel	Acier	Acciaio	Acero	Stahl	Stål	Staal	Staal
Variety A.				**Variety A.**			
Called steel because cast initialy into a malleable mass. 1. Soft or low carbon steel, or ingot iron	Acier doux, acier extra doux, fer fondu	Lingotto di ferro omogeneo (acciaio dolce)	Hierro fundido	Flußeisen[1]	Götmetall	Staal Blödstaal	Smeltyzer Vloeiyzer
2. Half hard and hard, or medium and high carbon steel, or ingot steel	Acier fondu, acier mi-dur, acier dur	Lingotto d'acciaio, duro, semi-duro	Acero fundido	Flußstahl[1])	—	Haardtstaal	Vloeistaal
Sub-Varieties				**Sub-Varieties**			
Bessemer steel	Acier Bessemer	Acciaio Bessemer	Acero Bessemer	Bessemer-Flußeisen Bessemer-Flußstahl	Bessemerstål	Bessemer staal	Bessemer staal
Open hearth steel	Acier Martin Siemens, acier sur sole	Acciaio Martin	Acero de Solera	Flammofen-Flußeisen Flammofen-Flußstahl	Martinstål	Martinstaal	Frischstaal, Siemens-Martinstaal
Crucible steel	Acier au creuset	Acciaio al crogiuolo	Acero de crisoles	Tiegelflußeisen Tiegelflußstahl	Degelstål or Degelgjutstål	Digelstaal	Kroerzenstaal
Cast steel	Acier au creuset	Acciaio fuso	Acero fundido	Gußstahl	Gjutstål	Stöbestaal	Gietstaal
Steel castings	Moulages d'acier	Pezzi di acciaio colato	Piezas de acero colado	Flußwaren	Stålgjutgods	Staalstöbegods, or Facongods	Vormgietstaal
Variety B.				**Variety B.**			
Weld steel, or wrought steel called steel because it is capable of hardening greatly by sudden cooling	Fer fort ou fer dur	Acciaio saldato Acciaio fucinato	Acero Soldado	Schweißstahl or Schweißeisen[1])	Wäll stål, rarely used, no equivalent	Svejsestaal	Welyzer Welstaal
Sub-Varieties				**Sub-Varieties**			
Blister steel, also called cemented and converted steel	Acier poule, acier cémenté, acier de cémentation	Acciaio cementato Acciaio al crogiulo Acciaio a carburazione esterna cementato	Acero cementado	Zementstahl	Blåsstål, Brännstål, Cementstål	Blaerestaal or Cementstaal	Cementstaal
Shear steel	Acier rafiné une fois corroyé	Acciaio damascato (acciaio saldato)	—	Schweißstahl	--	Svejsestaal	Welstaal
Puddled steel	Acier puddlé	Acciaio pudellato	Acero Pudelado	Puddelstahl	Puddelstål	Puddelstaal	Puddelstaal
Variety C.				**Varinty C.**			
Alloy steels	Alliages à base de fer, aciers spéciaux	Lega di acciaii (acciai speciali)	Aleaciones de Acero	Sonderstahl	Special stål	Special staal	Specialostaal
Species				**Species**			
Wrought iron (or weld iron, or, in Great Britain, malleable iron)	Fer soudé	Ferro fucinato Ferro saldato	Hierro forjado Hierro soldado	Schmiedeisen and Stabeisen	Smidesjern Lancashire jern	Svejsejern	Welyzer
Varieties				**Varieties**			
Puddled iron	Fer puddlé	Ferro pudellato	Hierro pudelado	Puddeleisen	Puddeljern	Puddjern	Puddelyzer
Bloomary or knobbled iron	Fer au bois (obtenu au Bas-Foyer)	—	—	Herdfrischeisen	Laneashire Franche-Comté or Walloon jern	Haerd frisket jern (always refers to Lancashire iron from Sweden)	Puddel of frischyzer

[1]) According to Wedding cast metal having a tenacity greater than 50 kg per sq. mm should be called Flußstahl, while with a smaller tenacity it should be called Flußeisen. Weld metal with a tenacity exceeding 42 kg per sq. mm should be called Schweißstahl and with a less tenacity, Schweißeisen.

Names			
German	Swedish	Danish	Dutch
Species			
Stahl	Stål	Staal	Staal
Variety A.			
Flußeisen[1])	Götmetall	Staal Blödstaal	Smeltyzer Vloeiyzer
Flußstahl[1])	—	Haardtstaal	Vloeistaal
Sub-Varieties			
›ssemer-Flußeisen essemer-Flußstahl	Bessemerstål	Bessemer staal	Bessemer staal
nmofen-Flußeisen nmofen-Flußstahl	Martinstål	Martinstaal	Frischstaal, Siemens-Martinstaal
Tiegelflußeisen Tiegelflußstahl	Degelstål or Degelgjutstål	Digelstaal	Kroerzenstaal
Gußstahl	Gjutstål	Stöbestaal	Gietstaal
Flußwaren	Stålgjutgods	Staalstöbegods, or Facongods	Vormgietstaal
Variety B.			
chweißstahl or Schweißeisen[1])	Wäll stål, rarely used, no equivalent	Svejsestaal	Welyzer Welstaal
Sub-Varieties			
Zementstahl	Blåsstål, Brännstål, Cementstål	Blaerestaal or Cementstaal	Cementstaal
Schweißstahl	--	Svejsestaal	Welstaal
Puddelstahl	Puddelstål	Puddelstaal	Puddelstaal
Varinty C.			
Sonderstahl	Special stål	Special staal	Specialostaal
Species			
hmiedeisen and Stabeisen	Smidesjern Lancashire jern	Svejsejern	Welyzer
Varieties			
Puddeleisen	Puddeljern	Puddjern	Puddelyzer
Herdfrischeisen	Laneashire Franche-Comté or Walloon jern	Haerd frisket jern (always refers to Lancashire iron from Sweden)	Puddel of frischyzer

. mm should be called Flußstahl, while with a smaller tenacity it should be called Fluß-
with a less tenacity, Schweißeisen.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

VIII 11

CONNECTION BETWEEN THE PERMANENT SETS CAUSES BY TRACTION AND COMPRESSION.

By Dr. Ing. **William Misángyi,** Budapest.

Translated from the German by Dr. H. Borns, London.

When we wish to determine the connection between the permanent deformations caused by traction and by compression, we have to characterise the deformation This is most perfectly attained by the aid of diagrams which represent the specific stresses as a function of the specific alteration of some dimension. Both Mr. Rejtő[1]) and Mr. Mesnager[1]) have adopted this method, but we know that their results differed.

Mr. Rejtő calculates the different forces acting upon the altered cross-section, the tensile and compression stresses, and the specific increments in the measurements. It should be emphasised that, as Mr. Rejtő says, "the alteration in the internal friction must be of the same value with stresses of various kinds, when the resulting increase in the dimensions, expressed in per cents, is the same". [2])

When the stresses of tension and of compression are plotted as ordinates and the specific increases in the dimensions as abscissae, we obtain tension curves according to Rejtő. In these curves of tension and compression those stresses will go together which correspond to the same specific increase in same dimension. When the compression stress is compared with the respective tension

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1) Congrès international des méthodes d'essai des matériaux de construction, Paris 1900.

2) Rejtő, "Der Wert der inneren Reibung", Baumaterialienkunde, 1904.

stress in the case of a tough material, near the limit of the tenacity it will result that this ratio is tan β, when β is the angle of sliding (and $\beta > 45^0$).

Mr. Mesnager likewise in constructing his diagrams makes use of the stresses which belong to the altered cross-sections. His abscissae are of a different kind, however. He deduces that in order to characterise the alterations in the dimensions, we should with tension apply $\log(1 + \lambda)$, and with compression $\log(1 - \varepsilon)$, where λ is the increase in length produced by tensile stress, and ε is the specific diminution in the length corresponding to compression; the logarithms are natural. The thus obtained stress curves of tension and compression should coincide, according to Mesnager, as long as the original states were the same with tension and with compression.

When we designate the compression stress by q, the tensile stress by p, and the sliding angle by β ($> 45^0$), then

Mr. Rejtő's equation is:

$$\frac{q}{p} = \tan\,\beta \qquad (1)$$

Mr. Mesnager's:

$$\frac{q}{p} = 1 \qquad (2)$$

A third equation, due to Duguet, should be added:

$$\frac{q}{p} = \tan^2 \beta. \qquad (3)$$

This last equation has been deduced by a purely mathematical method. The stresses have the indicated magnitudes, and Mr. Mesnager has indeed likewise arrived at this equation; but he remarks that his experiments approximately gave the value unity for this ratio, and that the third equation hence lacks justification.

Nor have I found any results that would justify this third equation. All the more satisfactory are the conclusions as to the first and second equations, to which my experiments have led me[1]).

The stress-strains diagrams furnished by the machines have enabled me to plot stress curves according to Rejtő and to

[1]) The experiments have been conducted at the Technical High School at Budapest, with the aid of the recording Rejtő testing machines. The results have been published in the Wochenberichte des Ungar. Ingenieurvereines, 1908.

Mesnager. The compression stress curve of Rejtő goes somewhat higher up than his tension stress curve; on the Mesnager method the two curves coincide.

Although it is in general very difficult to determine the angle of sliding accurately, I have yet succeeded in demonstrating experimentally, that equation 1 and the determination of the angle of sliding yield the same value; thus equation 1 may be considered to have been confirned by these experiments.

Equation 2 is confirmed by the curves which have been prepared after Mesnager. They coincide so beautifully that the inequalities in the material are greater than the differences between the tension and the compression curves.

It would result, therefore, 1. that the tension and compression curves plotted according to Professors Rejtő and Mesnager are not in contradiction to one another and that they can co-exist; 2. that equations 1 and 2 may be accepted as correct, simultaneously and jointly, because they both agree with the experiments; the tension and compression stresses merely appear differently chosen.

According to Professor Rejtő the co-ordinated tension and compression stresses are chosen in such a way, that when λ signifies the specific increase in length due to tension, and ε the specific diminution in length due to compression, the following equation will hold for λ and ε:

$$(1+\lambda)^2 \, . \, (1-\varepsilon) = 1 \tag{4}$$

While according to Mr. Mesnager

$$(1+\lambda) \, (1-\varepsilon) = 1 \tag{5}$$

which follows from the respective theories.

In deducing the tension and compression curves we want the same experimental data, whether we proceed by the Rejtő or the Mesnager method; only the abcissae are represented in different ways. Consequently we can derive the stress-strain diagrams of Mr. Rejtő from those of Mr. Mesnager and vice versa, so that one kind of stress will suffice for the determination of the angle of sliding.

In the case of a pull, we first plot the tensile stress curves according to Mr. Mesnager and to Mr. Rejtő. With the Mesnager method, this curve will likewise represent the thrust curve, while the Rejtő thrust curve can be calculated from it. The two Rejtő

curves will suffice for the determination of the angle of sliding by equation. (1)

When we merely possess compression data, the compression stresses are first plotted according to Mr. Mesnager and to Mr. Rejtő, and by calculation we obtain from the Mesnager compression stress curve — which may also be regarded as the tensile strength curve — the Rejtő tensile stress curve. When we have obtained the two Rejtő stress curves, the angle of sliding can again be determined.

We have to point ont that the tensile stress curve of Mr. Mesnager only permits of determining the first half of the Rejtő compression curve. The derivation of the second half requires an analytical treatment of the curve. For this purpose the Mesnager curve is suitable replaced by a parabola, by which means we are not only enabled to construct the unknown second half of the Rejtő curve, but we also obtain a formula for calculating the angle of sliding for tension. This formula is:

$$\frac{q_e}{p_e} = \tan \beta_e = 2{\cdot}414 - 1{\cdot}414 \frac{p'}{p_e} \tag{6}$$

in which q_e is the compression stress, p_e the tensile stress for the limit of tenacity, and p' is a tensile stress which corresponds to the abscissa λ', for which the formula:

$$1 + \lambda' = \sqrt{1 + \lambda_e} \tag{7}$$

is valid.

Since the quantities p' and p_e which occur in formula 6 can directly be derived from the stress-strain diagram — which has been recorded by the machine — we need not plot the stress curve when we wish to determine the angle of sliding.

The experiments shewed that the angle of sliding deduced from the formula agreed well with the experimental angle.

We find, therefore, with regard to the relation between the theories of Professors Rejtő and Mesnager, that the angle of sliding can be determined from one kind of stress. When tensile stress is applied, the determination can be effected by means of a convenient formula.

In all the special cases, therefore, in which only one kind of stress can be applied, when the shape or the small dimensions of the available test piece permit either only tension or only compression tests, this method will prove a good expedient.

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VIII₁₂

TENACITY AND MALLEABILITY.

By Dr. Ing. **William Misángyi**, Budapest.

Translated from the German by Dr. H. Borns, London.

Most investigators consider that the deformations which a body undergoes under stress indicate a sliding of the particles of the solid body. While this sliding lasts, the friction between the particles has to be overcome, and these frictional forces form those internal resistances which the external force has to overcome when a permanent set results.

According to Mr. Rejtő the internal friction is a function of the cohesion and of the coefficient of friction. When both these factors are constant, the internal friction will likewise be constant; when the cohesion or the coefficient of friction varies, the internal friction will likewise be changed.

Mr. Rejtő designates as malleable (bildsame) materials those whose internal friction is constant, and as tenacious (zähe) materials those, in which the internal friction increases while a permament deformation is taking place.

The property of being shapable (Formbarkeit) therefore consists in a tenaticy and in a malleability. All shapable materials are either tenacious or malleable or tenacious and malleable. The case occurs pretty frequently that a material, whose internal friction increases, will still posses a further power of being shaped even after this internal friction has attained its maximum value; in this change of shape, however, the maximum internal friction attained will be constant. Such materials are in the first instance tenacious and become afterwards malleable.

The Hungarian Association for Testing Materials has in late years discussed the uniformity of the tenacious deformation and the behaviour of the malleable materials. As regards the former problem Mr. Rejtő asserted on the strength of his traction tests, that the permament deformation was uniform during the period of tenacity. Mr. Bartel, on the other hand, observed in his tests that the test rod often turned conical during the period of tenacity. In order to elucidate this question I have conducted experiments for which I selected typical kinds of iron, soft, medium hard, and hard. My chief task was the accurate measurement of the cross-sections. My observations concerned nine cross-sections of rods, 100 mm in useful length and 8 mm in diameter. The original cross-section was not strictly cylindrical to start with; it displayed even in the very carefully selected tests rods differences of from 0·19 to 0·25%, and in the other test rods differences of 1 or 2% in the cross-section. Thus with a cross section of 50 mm² discrepancies of 0·1, respectively of from 0·5 to 1·0 mm² were observed in the maximum and minimum cross-sections. The tensile strength test was interrupted each time when an elongation of 5% was noticed, and was only continued after an accurate determination of the cross-section.

These tensile tests demonstrate: 1. that the accuracy of the original shape has a great influence upon the development of the permament deformation; 2. that the altered shape of the rod retains the character of the initial shape; 3. as a consequence of the want of homogeneity in the material, a smallest cross-section will only then be noticed at some spot when the original rod had very carefully been worked; otherwise the originally smallest cross-section will remain the smallest during the permament deformation, but the difference between this cross-section and the maximum cross-section will go on increasing; 4. the altered shape of the test rod may appear conical after a tough deformation, provided the initial shape was already conical; at first this feature will not be noticeable on account of the small difference in the cross-sections; after a certain tenacious permament deformation the difference will be greater, however, and the conical character will be more perceptible. When the

original shape is truly cylindrical, i. e. when the test rod has all over its gauge length exactly the same diameter, the deformation will be uniform with a homogeneous material. When however the test rod has not been carefully prepared, so that the cross-sections differ considerably, every cross-section will naturally undergo a diminuation corresponding to its load.

The elucidation of the second problem, the behaviour of malleable materials, necessitated the following experiments.

30/60 mm rolled iron, from Salgó-Tarján, was first tested in the state in which we received it. We then prepared specimens of a cross-section of 30 by 30 mm. These specimens were broken in a Werder-Maschine, solely for the purpose of producing a material which did not differ from the original in any other way, but that it had been put under tensile stress. Of the rods which had been submitted to this stress we prepared four pieces which were slowly stretched by cold hammering to such an extent that their cross-section was reduced to one-eighth.

The comparative experiments made with the broken and the original material proved that the simple traction sufficed to destroy the greatest portion of the tenacity. Since, as was already mentioned, it happens frequently that the cross-sections differ by relatively large amounts from the start, the smallest cross-section will, at the completion of the tenacious deformation of the test rod, already have suffered a diminution which will correspond to the real exhaustion of the tenacity at that spot, while the larger cross-sections will yet be more or less remote from this condition. A small portion of the tenacity will hence remain unexhausted in the thicker parts of the rod, because the stress cannot any further be increased. This is, in our case, the cause why only the greastest portion of the tenacity, but not the entire tenacity, was nihilated by the breaking test.

The tension tests of the material stretched in the cold indicated already by the appearance of the stress-strain diagram that the material did not any longer possess any tenacity in that state. The stresses increased along a steeply ascending straight line. The maximum was quickly reached, and the contraction followed at once, so that a diminution of the cross-section was noticeable only near the spot of the contraction. In this way

there resulted the value 0, for the uniform elongation and for the tenacity, but for the maximum strength and the maximum hardness the average value 74·70 kg/mm^2, while the original strength had been 33·55 kg/mm^2 and the maximum hardness 40·63 kg/mm^2.

The compression tests of the cold-stretched material indicated likewise, that the material had entirely lost its tenacity and had merely remained malleable. That is to say, the material still possessed a kind of plasticity which was only possible, however, with a constant internal friction. The compression stresses have been calculated for the altered unit cross-section and they were found to be constant until the height of the compressed specimen had become too small by comparison with the diameter.

We thus recognise that the tenacity is diminished and even altogether destroyed by stress applied in the cold, but not the malleability.

A further difference should be noted between the original material and the material after having been stretched in the cold; the cohesion rose from 118·7 kg/mm^2 to 169 kg/mm^2. Microscopic examination confirmed the assumption that the increase in the cohesion was to be ascribed to the finer grain structure; the original material showed large crystals and a coarse grain, while the stretched material displayed a very fine grain.

The originally tenacious and malleable material has hence altogether lost its tenacity by being forged in the cold, while retaining its malleability. The thus produced material still possessed hence a kind of plasticity corresponding to a constant internal friction. This is the malleable deformation. The substance affords a beautiful example of a merely malleable material which also possesses a very high strength. The original strength was raised to more than double its value, from 33·55 kg/mm^2 to 74·70 kg/mm^2, by the cold forging process; yet the material had not turned brittle; it still remained shapable, because the malleability could not be destroyed, nor diminished.

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IX1

REPORT OF THE COMMITTEE ON REINFORCED CONCRETE.

Presented by the Chairman of Committee No. 41, Prof. **F. Schüle**, of Zürich.

Translated by A. R. Liddell, Charlottenburg.

In accordance with a decision of the Brussels Congress, the Council nominated an international committee in 1907 for the study of reinforced concrete, the chairmanship of which M. Considère, of Paris, was good enough to accept. M. Considère, though remaining on the committee, found himself obliged, at the beginning of 1908, to give up his presidential functions. These were, at the invitation of the Council, accepted by the reporter.

In the spring of 1909 the committee was constituted as follows:

Chairman: *F. Schüle,* Professor am Eidg. Polytechnicum und Director der Eidg. Materialprüfungsanstalt in Zürich.

Vice-Chairman: *Germelmann,* Geh. Oberbaurat im Ministerium der öffentlichen Arbeiten, Berlin.

A. W. Talbot, Professor of the University of Illinois, Urbana, Illinois.

Members: *W. H. Warren,* Professor of Engineering, University of Sydney.

Paul Christophe, Ing. principal des ponts et chaussées à Bruxelles.

T. Grut, Captain in the Royal Danish Engineer Corps, Copenhagen.

E. Suenson, Professor of the Royal Technical College in Copenhagen.

Bürstenbinder, Baurat der städtischen Baupolizei, Hamburg.

Alf. Hüser, Engineer, of Obercassel.

Dr. Ing. A. Martens, Professor, Geh. Ober-Regierungsrat, Direktor des kgl. Materialprüfungsamtes, Groß-Lichterfelde W.

E. Züblin, Engineer, of Straßburg i. E.

Max Clarke, F. R. I. B. A., London.

William Dunn, Representative of the Concrete Institute, London.

Edwin O. Sachs, F. R. S. E., Chairman of the British Fire Prevention Committee, London.

Dr. W. C. Unwin, Professor, Representative of the Institution of Civil-Engineers, London.

A. Considère, Insp. gén. des ponts et chaussées, en retraite, Paris.

R. Feret, chet du lab. des ponts et chaussées, Boulogue-sur-mer.

A. Mesnager, Professeur, Ingénieur en chef des ponts et chaussées, directeur des lab. à l'Ecole des ponts et chaussées, Paris.

Ch. Rabut, Ing. en chef des ponts et chaussées, Versailles.

M. Tricon, directeur de la Société des travaux en béton armé, Paris.

S. J. Rutgers, Engineer in the municipal Building Office, Rotterdam.

Silvio Canevazzi, Professor at the Engineer's School in Bologna.

Camillo Guidi, Professor at the Engineers School in Turin

Claudio Segré, Chief-Engineer of the State Railway Testing Institution, of Rome.

The Royal Norwegian Roads-Directorate, of Christiania.

V. Brausewetter, Engineer, Concrete-Building Contractor, Vienna.

Dr. v. Emperger, Oberbaurat, Vienna.

B. Kirsch, Professor der k k. technischen Hochschule, Vienna.

J. Melan, Professor der k. k. deutschen technischen Hochschule, Prague.

Dr. N. Belelubsky Excellence, Professeur, Directeur du Labor. méc. de l'Institut imp. des voies de comm., St. Pétersbourg.

S. Droujinine, Prof. à l'Institut polytechnique de St. Pétersbourg.

R. Maillart, Engineer, of the firm of Maillart & Co., of Zurich.

Desiderius Nagy, Professor at the Polytechnikum, Budapest.

Samuel Pecz, Professor at the Polytechnikum, Budapest.

Joseph Schustler, Civil-Engineer, Budapest.

Dr. Richard Zielinski (Szilard), Professor at the Polytechnikum, Budapest.

E. Turneaure, Dean of the College of Mechanics and Engineering, Madison, Wisconsin.

The Committee met in October 1908 at Bâle, 19 members representing 9 countries, taking part in the proceedings. The principal subject for discussion was the establishment of a programme of work for the Committee, especially in view of the coming Congress in Copenhagen. The decisions arrived at were the following:

1. A representative of each country shall give an abstract, in such form as he considers suitable, of the scientific investigations undertaken or proposed to be undertaken on the domain of reinforced concrete.

2. This report shall indicate the measures adopted for the inspection of reinforced concrete in the country in question.

3. A sub-committee shall draw up an agreement on the subject of uniform notation in the static calculations appertaining to reinforced concrete and as to the uniform grouping of the data and test-results, so as to facilitate the study of scientific works relating to this material. This committee includes the following members: Messrs. Melan (Prague), Mesnager (Paris), Maillart (Zürich), Rutgers (Rotterdam), and Sachs (London).

4. Finally two reporters were nominated to deal with the two following important questions:

Herr v. Emperger (Vienna): Casualties in Reinforced Concrete Building, and M. Rabut (Paris): The Experimental Study of Completed Buildings.

Reports were received by the chairman in relation to points 1 and 2 from the following gentlemen:

Geheimrat Germelmann for Germany,
Professor Benetti for Italy,
Professor Suenson for Denmark,
Engineer Rutgers for Holland and
M. Schüle for Switzerland.

These reports are published in full, as annexes, in the original languages, and serve to show the progress made in the methodical testing of reinforced concrete.

The most important and complete of the investigations are still proceeding, and although it is not very likely that they will result in important modifications in the deductions made from earlier experiments, it will nevertheless be better to await their results before formulating definite conclusions in regard to the numerous problems connected with reinforced concrete. The action of the Committee will be greatly hampered by this circumstance.

It will not, however, be necessary to wait for what the greater number of analogous experiments in existence enable to be calculated with more precision, viz. the internal strains set up in a reinforced concrete structure under the influence of external forces. It will always be necessary to distinguish between two groups of questions, which are to be solved by these tests:

a) The progress of the phenomena and of the deformations occurring under the action of external forces, varying as these do according to the arrangement of the iron and of the concrete, as also according to the composition and the manufacture of the latter material, in fact the descriptive experimental study of reinforced concrete.

b) The determinations of the amounts of the internal strains from the initial deformations up to the moments of rupture, so as to establish the effective degree of safety corresponding with a given load, and the stresses to which the metal and the concrete may be subjected. This is the study of the strength of reinforced concrete.

The progress of the phenomena and deformations can be described with sufficient exactness without the use of absolute figures. This study will contribute towards the formation of the judgment of the engineer.

In the study of the strength, the figures are everything, but for concrete their limits of variation are so extensive, that in practice any considerable precision is out of the question as soon as the concrete plays the principal part in the absolute strength of a portion of the structure. A design, made by the aid of what is called statical calculation, is and remains an approximation, which supplies the proof that under normal or even average conditions of actual work the interior stresses maintain themselves at a somewhat low figure in order that the safety of the construction may be guaranteed.

The method of calculation could not be based on the more favourable of the results obtained, but must be adapted to those given by concrete of a less excellent quality.

The International Association has opened up an immense field for its labours in the admission of the study of reinforced concrete to its programme. In connection with other materials of construction, it is essentially the methods of testing of which it takes cognisance; would it not, as regards reinforced concrete, have been more correct to limit the domain of the Association's investigations? With a view to the attainment of results of a general and scientific character, it would have been advisable to exclude everything, the applications of which, including even the relative values of the different systems of reinforcement, are aimed at a certain fixed problem of construction.

The task then becomes concentrated:

1. on the general study of the properties of reinforced concrete tested by bending, compression, shearing etc., that is to say, by external forces;

2. the study of the physical properties of reinforced concrete, especially of the influence of temperature, of shelter from the air, and of expansion under water;

3. the study of the influence of external agents, such as fresh water, salt water, aqueous vapours, smoke, sulphurous acid, ammonia, oil, tar, and electric currents;

4. the study of accidents and their causes;

5. the study of practical methods for the testing and the periodical inspection of reinforced concrete.

All these investigations have already been made the subject of important work in several countries; it would be the essential task of the Association to group the results obtained, in so doing to give a useful impulse to the remaining investigations, and to establish a permanent connection between the engineers who are giving their attention to these questions.

It is the province of the Committee to establish a more precise programme of the work to be done between one congress meeting and the following one, for it is not likely that all the questions can be attacked simultaneously; it would be a good plan to concentrate the discussion at the Congress on the course to be

followed in the works of investigation, so as to give the Committee directions in harmony with the views of the Members of the Association.

The task proposed for the Sub-Committee presided over by Prof. Melan has for its aim the simplification of the work of comparison of the results of the investigations, whether by the use of identical methods of notation, or by the systematic and uniform indication of all the elements which are met with in each series of tests. The first portion of this task has taken the form of a complete nomenclature of notation, which will be submitted to the Committee before it is embodied in a proposal to be laid before the Congress.

A preliminary work of supreme importance is here in question.

IX 1 a

WISSENSCHAFTLICHE VERSUCHE UND VERSUCHE ZUR KONTROLLE DER BAUAUSFÜHRUNG AUF DEM GEBIETE DES EISENBETONBAUES IN DEUTSCHLAND.

Mitgeteilt vom Deutschen Ausschuß für Eisenbeton, Berlin.

Mit der Entwicklung des Eisenbetonbaues in Deutschland lief die Ausführung einer großen Anzahl von Versuchen Hand in Hand, an denen die verschiedensten, auf dem Gebiete des Eisenbetonbaues arbeitenden Firmen und Forscher beteiligt waren.

Einer besonderen Förderung hatte sich die Versuchstätigkeit zu erfreuen durch den vom Kuratorium der Jubiläumsstiftung der Deutschen Industrie im Jahre 1903 ins Leben gerufenen Ausschuß, dem es obliegen sollte, die wissenschaftliche Forschung auf dem Gebiete des Eisenbetonbaues in systematischer Weise aufzunehmen und zwar unter Würdigung der bis dahin auf diesem Gebiete durchgeführten Versuche, sowie unter Berücksichtigung der Bedürfnisse der ausführenden Technik.

Ferner wirkten anregend auf die Durchführung von Versuchen der Erlaß der preußischen vorläufigen „Bestimmungen für die Ausführung von Konstruktionen aus Eisenbeton bei Hochbauten vom 16. April 1904", sowie das Erscheinen der vom Verbande Deutscher Architekten- und Ingenieur-Vereine und dem Deutschen Betonverein im Jahre 1904 aufgestellten „Vorläufigen Leitsätze für die Vorbereitung, Ausführung und Prüfung von Eisenbetonbauten".

Einen Mittelpunkt aller dieser Bestrebungen bietet der im Jahre 1907 vom preußischen Minister der öffentlichen Arbeiten berufene Deutsche Ausschuß für Eisenbeton, welcher Vertreter des Deutschen Reiches und aller größeren deutschen Staaten, die

Vorsteher der sämtlichen deutschen technischen Versuchsanstalten, Abgesandte des Verbandes deutscher Architekten- und Ingenieur-Vereine, des Deutschen Betonvereines, des Vereines deutscher Portlandzement-Fabrikanten, des Vereines deutscher Ingenieure, des Vereines deutscher Eisenhüttenleute und andere auf dem Gebiete des Eisenbetons erfahrene Männer vereinigt, um die vielen noch offenen Fragen einer Lösung entgegenzuführen. Dieser Ausschuß beschäftigt sich zur Zeit mit der Planung und Durchführung von Versuchen auf Grund nachfolgender drei Arbeitspläne.

Arbeitsplan I.

Der Arbeitsplan I bezweckt die Erforschung der Eigenschaften des Betons, er umfaßt die Versuche mit reinen Betonkörpern.

Die Versuche sind zerlegt in Druckversuche, Biegeversuche, Zugversuche, Drehversuche und Scherversuche. Bei den Druckversuchen sind Nebenreihen vorgesehen zur Ermittlung der gesamten und der bleibenden Formänderungen, bei den Biegeversuchen Nebenreihen mit verschiedenen Abmessungen der Versuchskörper, bei den Zugversuchen Nebenreihen mit wechselnder Zug- und Druckbeanspruchung der Versuchskörper.

Zur Verwendung gelangen in zwei verschiedenen Mischungsverhältnissen hauptsächlich zwei charakteristisch von einander verschiedene Sand- und Kiesmaterialien. Die Druckversuche werden mit zweierlei Zementen und mit zweierlei Wasserzusätzen durchgeführt. Hierzu kommen Zusammensetzungen von Sanden mit Steinschlag, von Quetschsanden mit Steinschlag und von Schlackensanden mit Steinschlag.

Die Körper werden teils in zwei, teils in drei, teils in fünf Altersklassen geprüft und zwar nach 28 Tagen, 90 Tagen, 1 und 2 sowie x Jahren.

Arbeitsplan II.

Der Arbeitsplan II behandelt die Beobachtung des Verhaltens von Eisen im Mauerwerk.

Durch die Versuche soll ermittelt werden:

1. ob Eisen in verschiedenartigem Mauerwerk mehr oder weniger dem Rostangriff ausgesetzt oder davor geschützt ist;

2. welche Haftfestigkeit zwischen dem Mörtel und der Oberfläche des Eisens eintritt;

3. ob und welchen Einfluß eine verschiedenartige Oberflächenbeschaffenheit des Eisens, Anstrich, Rostdecke, Verzinkung usw. auf die genannten Eigenschaften ausübt, ob die größere oder geringere Entfernung der Eiseneinlage zur Außenfläche des Versuchskörpers von Einfluß ist und ob chemische Verbindungen zwischen Mörtel und Eisen anzunehmen sind.

Zur Klärung dieser Fragen sind drei Gruppen von Versuchen vorgesehen:

a) Versuche auf Haftfestigkeit und Rosten an Körpern aus Ziegelmauerwerk und aus Bruchsteinmauerwerk, das Mauerwerk mit verschiedenen Mörteln hergestellt, Lagerung in der Luft.

b) Versuche auf Rosten und chemisches Verhalten an kleinen Mörtelkörpern.

c) Versuche auf Dauer und Rostangriff, eventuell auf Haftfestigkeit mit Eisenstäben in Mauerkörpern von verschiedenem Mörtel bei Lagerung in der Luft und in verschiedenen Wässern.

Arbeitsplan III.

Da der Arbeitsplan III für den Eisenbetonausschuß des Internationalen Verbandes für die Materialprüfungen der Technik von besonderem Interesse ist, wird er im folgenden ausführlicher mitgeteilt.

Übersicht über den vorläufigen Arbeitsplan III Eisenbetonversuche.

I. Allgemeine Versuche.

A. Versuche über den Gleitwiderstand und Rostschutz.

a) Vorversuche.

1. Einfluß des Wasserzusatzes, Einfluß verschiedener Sande und Zuschläge, Einfluß des Mischungsverhältnisses.

2. Einfluß der Oberflächenbeschaffenheit des Eisens.

Zug- und Biegungsversuche mit Rundeisen von verschiedenem Querschnitt, blank, Handelseisen mit Walzhaut ohne Rost, von losem Rost gereinigtes Eisen, rostiges Eisen, eingeschlemmtes Eisen.

Zug- und Biegungsversuche mit Handelseisen, und zwar mit Rundeisen, Winkeleisen, Flacheisen und Profileisen von gleicher Haftfläche.

Zug- und Biegungvsersuche mit gewöhnlichem Rundeisen, Kanteneisen, eingekerbtem Eisen, schraubenförmig gedrehtem Eisen usw.

3. Einfluß ungenügender Umhüllung der Eisen mit Betonmörtel.

Zugversuche mit Eisen nahe dem Rande und in der Mitte der Betonkörper.

Biegungsversuche mit Eisen ganz nahe dem unteren Rande der Betonkörper und mit Eisen, deren gegenseitiger Abstand sehr gering ist.

4. Einfluß der Erhärtung an der Luft, im Wasser, bei Frost, sowie unter dem Einfluß von Feuer und heißem Dampf.

5. Einfluß von Erschütterungen während der Herstellung und des Abbindens der Betonkörper auf den Gleitwiderstand.

6. Einfluß verschiedener Belastungsvorgänge bei Zug und Biegung.

Allmähliche Steigerung der Last.
Wiederholte Belastung.
Stoßweise Belastung.
Als Dauerversuch:

7. Versuche über den Rostschutz bei ganzen Konstruktionsteilen.

Mit rostigem und reinem Eisen bewehrte Betonplatten sollen unter ungünstigen Verhältnissen aufbewahrt und später belastet werden.

b) Hauptversuche.

1. Versuche zur Ermittlung der Größe des Gleitwiderstandes beim Herausziehen der Eisen aus dem Beton.

2. Versuche zur Ermittlung der Größe des Gleitwiderstandes bei Biegung.

Versuche an Platten und Plattenbalken.

B. Versuche über die Dehnungsfähigkeit des bewehrten Betons.

Versuche an rechteckigen Balken und an Plattenbalken.

Untersuchung der Nebenspannungen.

Verschiedene Bewehrungsprozente bei verschiedener Aufteilung des Eisenquerschnitts, verschiedene Mischungen und Wasserzusätze.

Erhärtung an der Luft und im Wasser, einseitige und allseitige Wärmebestrahlung.

Verschiedene Belastungszustände.

Vergleich mit unbewehrtem Beton.

Prüfung der durch die Vorschriften gegebenen Sicherheit gegen Zugrisse im Beton.

C. Versuche über die richtige Bewehrung gegen Schubkräfte.

Versuche an rechteckigen Balken und an Plattenbalken mit verschiedener Anordnung der Hauptbewehrung und der Bügel.

D. Versuche über den Einfluß der Stoßverbindungen im Eisen bei Zug, Biegung und Druck.

Versuche mit folgenden Stoßanordnungen:
1. Einfaches Übergreifen der Eisen.
2. Übergreifen der Eisen, die Enden sind mit Haken versehen.
3. Wie vor, jedoch mit Draht umwickelt.
4. Direkter Haken.
5. Stoß durch Lascheneisen.
6. Direkter stumpfer Stoß.
7. Stoß durch Schweißung.

II. Besondere Versuche mit einzelnen Konstruktionsteilen.

A. Versuche mit Balken und Platten.

1. Balken (Platte), rechteckiger Querschnitt, einfache Bewehrung, an zwei Seiten aufliegend.

Prüfung der Berechnungsmethode.

Bei der Auflagerung soll unterschieden werden:

Vollständig freie Auflagerung,

freie, seitlich geschlossene Auflagerung,

teilweise und volle Einspannung,

Zusammenwirken von Balken und Auflager als Rahmen.

2. Platte, rechteckiger Querschnitt, doppelte Bewehrung, an zwei Seiten frei aufliegend.

3. Platte, quadratisch und rechteckig, an allen vier Seiten frei aufliegend.

Feststellung einer Berechnungsmethode.

Berechnung parallel zu den Seiten und Bewehrung in Richtung der Diagonale.

4. Platte, an allen vier Seiten teilweise und voll eingespannt.

5. Durchgehende Platte über drei Stützen.

a) Feste Stützen, gleiche Feldweiten, frei drehbare Auflager.

b) Elastische Stützen, gleiche Feldweiten, frei drehbare Auflager.

c) Feste Stützen, gleiche Feldweiten, Auflager nicht frei drehbar, teilweise eingespannt.

d) Durchgehende Platte über frei aufliegenden Rippen aus Eisenbeton.

e) Durchgehende Platte über frei aufliegenden I Trägern unter gewisser Anspannung der Oberflanschen der Träger.

6. Durchgehende Platte über 3 Stützen, aber mit ungleicher Felderteilung.

B. Versuche mit Plattenbalken.

1. Versuche mit einfachen Plattenbalken.

a) Versuche über den Einfluß der Deckplattenbreite, Aufschluß über die Mitwirkung der Platte als Druckgurt, Prüfung der zur Zeit angewandten Berechnungsmethode.

b) Feststellung des Einflusses aus dem Verhältnis der Deckplattenstärke zur Deckplattenbreite und zur Rippenhöhe auf die Mitwirkung der Platte als Druckgurt.

c) Feststellung des Einflusses der doppelten Beanspruchung der Platte in zwei senkrecht zueinander stehenden Richtungen auf die Biegungsfestigkeit der Platte. Vergleich mit einfach beanspruchten Platten.

d) Versuche mit Randträgern, sonst wie bei a.

e) Versuche an Plattenbalken mit obenliegenden Rippen zur Ermittlung des Wertes einer Druckbewehrung an der Oberseite der Trägerrippen.

2. Versuche mit Randträgern und Gurtträgern.

Anordnung derart, daß sich die Druckspannungen in der Deckenplatte addieren. Ausdehnung des Versuches auf die Kassettendecke.

3. Versuche mit durchgehenden Plattendecken.

Drei feste Stützen, gleiche Feldweiten, frei drehbare Auflager, Plattenbalken mit und ohne Voute. Plattenbalken mit Bewehrung nach verschiedenen Gesichtspunkten.

C. Versuche mit Säulen.

1. Vorversuche über den Wert der verschiedenen Bügelbewehrung.

2. Vorversuche über die Wirkung der Aufteilung des Eisenquerschnittes der Bügelbewehrung.

3. Vorversuche über den Einfluß der Bügelstärken.

4. Hauptversuche:

a) mit Bewehrung durch Bügel,
b) mit Bewehrung durch Spiralen und Ringe,
c) mit Bügelbewehrung ohne Längsbewehrung,
d) Versuche zur Festsetzung der Knickfestigkeit.

Es sind ferner vorgesehen:

Versuche über Feuersicherheit,

Versuche über das Verhalten von Eisenbeton gegenüber Elektrizität.

Bemerkung: Näheres über die bis jetzt auf dem Gebiete des Eisenbetonbaues bereits durchgeführten und veröffentlichten Versuche sowie über die zur Zeit abgeschlossenen, aber noch nicht der Öffentlichkeit übergebenen Versuche findet sich in einem Verzeichnisse, welches auf dem Kongreß gesondert überreicht werden soll.

Versuche zur Überwachung der Bauausführung.

Zur Überwachung der Ausführung von Eisenbetonbauten sind in Deutschland bisher Versuche mit reinen Betonwürfeln üblich.

Durch die zur Zeit für Eisenbetonbauten in Geltung befindlichen Vorschriften wird bestimmt, daß die Würfel 30 cm Seitenlänge besitzen müssen.

Die im Jahre 1908 vom Deutschen Ausschuß für Eisenbeton aufgestellten „Bestimmungen für Druckversuche bei der Ausführung von Bauten aus Stampfbeton“ enthalten als Fußnote die Bemerkung, daß diese Bestimmungen für Probekörper aus Stampfbeton — sinngemäß angewandt — bis auf weiteres auch Geltung beanspruchen können für die Anfertigung und Prüfung von Probekörpern bei der Ausführung von Eisenbetonbauten.

Genauere Vorschriften für die Anfertigung der Versuchskörper bei der Ausführung von Eisenbetonbauten gibt es zur Zeit noch nicht. Der Schaffung solcher genauerer Vorschriften wird demnächst nähergetreten werden.

IX1b

EXPÉRIENCES ET ESSAIS DE CONTRÔLE SUR LE BÉTON ARMÉ EN ITALIE

Rapport de M. **J. Benetti** à Bologne.

Les études expérimentales sur la résistance des matériaux ont pris en Europe et en Amérique dans les dernières années un essor nouveau, en vue d'atteindre une amélioration sérieuse et permanente dans les procédés constructifs. A côté des Écoles pour les ingénieurs et des bureaux techniques des grandes administrations et des grandes usines, peu à peu se sont formés, presque partout, des laboratoires destinés à reconnaître les propriétés et les coefficients de résistance des matériaux employés couramment dans les constructions. L'Italie a suivi ce mouvement: une Association nationale pour l'étude des matériaux a été constituée dans notre pays, elle a su se faire valoir auprès du Gouvernement, de sorte que, en peu d'années, on est arrivé à établir des prescriptions officielles sur les qualités que les matériaux de construction doivent présenter, et à organiser un service de contrôle et d'essai pour les travaux de l'État. Les administrations publiques ou privées qui le désirent, peuvent en profiter pourvu qu'elles se soumettent au payement d'une faible redevance, fixée par un tarif officiel. L'Italie a été partagée en régions desservies chacune par un laboratoire expérimental d'essai. L'Administration des chemins de fer de l'État a installé à Rome un Institut central d'essai pour les matériaux et pour les travaux qui l'intéressent directement. Le service d'essai et contrôle pour les travaux courants, publics et privés, est fait par les laboratoires expérimentaux annexés aux Écoles des ingénieurs de Palerme, de Naples, de Rome, de Bologne, de Padoue, de Milan et de

Turin, à l'École navale de Gênes et à l'Institut technique de Florence.[1])

Tous ces laboratoires ont été créés, ou considérablement augmentés, dans un délai relativement assez court, en vue des expériences techniques, mentionnées dans les prescriptions officielles, et que maintenant ils exécutent couramment. Plusieurs d'entre eux cependant sont aussi pourvus, d'une manière plus ou moins complète, des moyens nécessaires pour entreprendre des expériences de nature scientifique. Des recherches intéressantes ont été faites sur les pierres naturelles et sur les métaux, mais ici il ne peut être question que des études concernant le béton armé, et incidemment de celles qui se rapportent aux agglomérants hydrauliques et aux mortiers.

A ce point de vue il faut rappeler avant tout les travaux très importants de l'Institut expérimental des Chemins de fer de l'État, qui ont parus presque seulement sous forme de cahiers de charge dans les publications:

a) Prescrizioni tecniche pei materiali da impiegarsi nei lavori delle Ferrovie dello Stato (Tip. G. Civelli, Roma 1908).

b) Capitolato generale tecnico di appalto delle opere, che si eseguiscono dall' Amministrazione delle Ferrovie dello Stato (Tip. G. Civelli, Roma 1906).

En suite il y a eu les séries d'expériences faites dans tous les laboratoires d'essai italiens pour le choix d'un sable normal. Le bulletin de l'Association italienne[2]) pour l'étude des matériaux contient des renseignements assez intéressants sur plusieurs recherches ayant caractère scientifique, entre autres; le mémoire sur la Granulométrie de M. G. Salemi, Pace; les expériences de M. M. Greco de Palerme sur la résistance des mortiers et des bétons à l'effort tranchant; et celles faites à Bologne par MM. S. Canevazzi et A. Landini d'abord sur l'influence que le façonnage des échantillons d'essai a sur les résultats des expériences, et après pour une étude sur l'emploi des mortiers secs et des mortiers plastiques dans les essais de laboratoire.

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[1]) Les directeurs de ces laboratoires sont, dans le même ordre, M. C. Segrè (Rome), M. G. Salemi-Pace (Palerme), M. E. Isè (Naples), M. C. Ceradini (Rome), M. S. Canevazzi (Bologne), M. V. L. Rossi (Padoue), M. A. Sayno Milan), M. C. Guidi (Turin), M. M. Panetti (Gênes), M. G. Bellotti (Florence).

[2]) On se rapporte aux publications faites par l'Association italienne pour l'étude des matériaux, car une analyse détaillée entraînerait trop loin.

Soit que l'attention des expérimentateurs italiens ait été attirée avec préférence sur les matières premières, soit aussi peut-être souvent à défaut de moyens suffisants, les travaux de recherche par rapport au béton armé ont été faits, mais la plupart du temps avec des vues industrielles. L'institut expérimental des Chemins de fer de l'État a fait plusieurs recherches intéressantes; entre autres sur les pieux en béton armé pour pilotis. A Bologne on a fait une étude comparative entre les dalles armées avec barrettes et celles contenant du métal déployé, et à Gênes, M. Panetti[1]) s'est livré à une analyse très intéressante et très remarquable sur la résistance des cylindres et des réservoirs.

M. L. V. Rossi a fait à Padoue des essais sur le béton armé et sur les conditions de résistance des constructions résultantes de la combinaison du métal avec le béton de ciment Portland. Le Génie militaire s'est occupé aussi d'une manière très-suivie du béton armé: les travaux du Général Caveglia et du Colonel Marzocchi sont très connus et appréciés. Une série cependant méthodique d'expériences et de recherches sur les propriétés du béton armé n'a été faite qu'à Turin, où M. C. Guidi, professeur à l'Ecole polytechnique essaye le béton armé depuis l'année 1900.

D'abord il a fait connaître les résultats des essais, qu'il a fait sur l'adhérence du fer au béton; sur l'élasticité et la résistance à la traction, à la compression, à la flexion; signalant l'action de frettage produite par l'armature dans les pièces comprimées.[2]) En 1901 M. Guidi rend compte d'autres essais du même genre

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[1]) Panetti. Una esperienza comparativa sulle travi in béton armé Hennébique (Ingegneria civile, Torino 1902).

Misura dell freccia di incurvamento come mezzo di collaudo delle costruzioni in cemento armato (Ingegneria civile, Torino 1903).

Studio statico dei serbatoi cilindrici in cemento armato (Genio Civile, Roma 1906).

Notizie sul laboratorio della R. Scuola Navale (Genova 1908).

[2]) Guidi. Esperienze sull' elasticità e resistenza dei conglomerati di cemento semplici ed armati. Due memorie. Atti della R. Accademia delle Scienze di Torino 1900—1901.

Risultati sperimentali sui conglomerati semplici ed armati. Atti della Società degli ingegneri e degli architetti di Torino 1905 e 1906.

Sull' unione dei ferri nelle costruzioni in beton armato. Atti della Società degli ingegneri ed architetti di Torino 1906.

Esperienza sull' elasticità e resistenza a compressione di una colonna in béton fretté.

sur les bétons de dosage différent et après en 1905—1906 il s'occupa de 300 essais, faits à la demande de la Commission du béton armé nommée par la Société des Ingénieurs de Turin. Il s'agit d'essais de laboratoire, aussi bien que d'essais sur piliers et sur poutres de grandes dimensions. Dans ce travail on considère l'action de la gelée sur le béton; l'influence du frettage, de la résistance au cisaillement, de l'adhérence et des efforts engendrés dans le fer pendant le durcissement du béton. En 1906 M. Guidi a publié une étude comparative sur la résistance des différents systèmes d'union des fers dans le béton armé, dont il avait été question au Congrès de Bologne en 1903; soudures ordinaires, soudures oxyacétyléniques; assemblages par manchons en écrous; assemblages par adhérence (superposition ou doublure des fers sur une longueur de 30 diamètres). Maintenant il a mis en train des essais sur des grandes poutres armées avec fers américains. Toutes ces expériences sont très-appréciées et ont beaucoup profité à la Commission italienne du béton armé.

Au commencement de l'emploi du béton armé, les essais de contrôle courant pour les constructions faites avec ce matérial n'étaient pas uniformes en Italie. Ordinairement les travaux étaient exécutés par des maisons spécialistes et on les recevait après un essai de chargement sans fissuration, souvent avec un poids égal à une fois et demie la charge prévue, avec la condition que la flèche de flexion ne dépassât pas le millième de la portée. Cette pratique, par trop empirique, a été l'objet de discussion au sein de l'Association italienne pour l'étude des matériaux, qui a fini avec la présentation d'un module de prescriptions pour les constructions en béton armé, approuvé au Congrès de Pérouse (1906). Ces prescriptions ont été acceptées en suite par le Gouvernement italien, et sont devenues officielles après l'arrêt ministériel du 10 janvier 1907. Dès cette époque les administrations publiques et privées tendent à uniformer leurs cahiers de charges aux règles établies par l'État, et l'on a raison de croire que bientôt celles-ci seront toujours suivies dans tous les travaux.

Les prescriptions officielles italiennes pour les ouvrages en béton armé ne diffèrent pas beaucoup de celles en usage dans les autres pays, et on peut en prendre connaissance par le journal „Le ciment" qui les reproduit dans les numéros 9 et 10 (septembre et octobre) de l'année 1906. Ces prescriptions demandent d'abord

un projet complet de l'ouvrage à bâtir avec calcul de résistance fait sur la base de la théorie limite supérieure [1]), c'est-à-dire en acceptant:

a) le principe de la conservation des sections planes;

b) la proportionnalité des efforts intérieurs à la distance que chaque élément de la surface résistante a de l'axe de rotation de la section, dans l'hypothèse que le métal résiste aussi bien à la traction qu'à la compression, que le béton résiste uniquement aux efforts de compression, et que le rapport m entre les deux modules d'élasticité soit constant et égal à dix ($m = 10$). Dans le cas de la tension ou compression simple, l'axe de rotation tombe à distance infinie; c'est-à-dire l'effort résistant est uniformément distribué dans la section effectivement résistante.

Ensuite les prescriptions officielles imposent un contrôle très exact des qualités des matériaux employés et des soins de mise en œuvre avec essais dans un laboratoire expérimental officiel. Finalement, avant que la construction achevée soit reçue, elle doit être soumise à un essai de chargement, sans fissurations et sans que la flèche ou déformation théorique soit dépassée.

La charge maximum par cm^2 admise pour le béton est un cinquième de la charge de rupture par compression, contrôlée sur cubes de 12 cm de côté, âgés de 28 jours.

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1) Canevazzi. Siderocemento. (Atti del Collegio degli ingegneri e degli architetti di Bologna 1901—1902).

Ferrocemento (Società Editrice successore A. F. Negro, Torino 1904).

IX1c

EISENBETONVERSUCHE IN DÄNEMARK.

Mitgeteilt von Prof. E. **Suenson** in Kopenhagen.

Von Versuchen, welche Bedeutung für die Eisenbetonbauweise gehabt haben, sind die vom Ingenieurkapitän Grut ausgeführten zu nennen. Er hat zuerst Zugelastizitätsversuche mit Beton gemacht und den Elastizitätsmodul bestimmt („Ingeniören" 1896, Seite 39 ff., kurz referiert in „Beton und Eisen" 1906, Seite 138), und später hat er sehr interessante Untersuchungen über das Wärmeleitungsvermögen des Betons angestellt („Den tekniske Forenings Tidsskrift" 1903, Seite 206). Die letzteren Versuche wurden mit zwei Hohlzylindern aus Beton von $1\,C + 1^1/_2\,S + 1^1/_2$ Kies und $1\,C + 2\,S + 3$ Kies gemacht. Der innere Durchmesser war 14 cm, der äußere 34 cm, die Höhe 51 cm. Der innere Hohlraum wurde mittels eines elektrischen Stromes bis zu 1000^0 erhitzt, und die Temperaturerhöhung in 1, 2, 3, 5, 7 und 9 cm Abstand von der Innenseite des Körpers wurde alle halbe Stunde mittels Le Chateliers Platin-Rhodium-Pyrometer beobachtet. Nach 7 bis 8 Stunden wurde der Gleichgewichtzustand erreicht, nämlich:

im Abstand	0	1	2	3	5	7	9 cm
Temperatur	1004	834	679	600	449	348	264^0 C.

Die Zahlen sind Mittelwerte aus beiden Zylindern.

Wenn bei einer Feuersbrunst eine Platte von unten erwärmt wird, steht das Eisen ungefähr unter denselben Bedingungen wie dasjenige Pyrometer, welches in 2 cm Abstand von der Innenseite des Hohlraumes entfernt war. Die Temperatur in diesem Punkte war im Mittel nach:

1	2	3	4	5	6	7 Stunden
259	424	537	601	637	659	675^0 C.

Die Betonkörper waren 3 Monate alt, aber der eine wurde vor dem Versuche bis zu 1000° im Innenraume erwärmt und wieder abgekühlt. Dadurch wurde das Wasser ausgetrieben und das Leitungsvermögen gesteigert, und dieser Körper war daher bei den Temperaturmessungen, aus welchen die obenstehenden Mittelzahlen gebildet sind, immer ungefähr eine Stunde vor dem anderen voraus.

Zugleich wurden Betonwürfel auf verschieden hohe Temperaturen erwärmt und nach Abkühlung zerdrückt; sie waren $2^1/_2$ bis 3 Monate alt (8 Tage im Wasser, sonst in der Luft). Die Ergebnisse sind:

Anzahl der Würfel:	5	5	5	5	2	2	2	3
Erwärmt zu:	Zimmertemperatur	100	150	200	300	500	700	1000° C.
Druckfestigkeit:	373·9	370·1	425·3	424·2	379·2	304·6	171·3	47·1 at.

Der Berichterstatter hat einige vergleichende Adhäsionsversuche mit Johnsons Knoteneisen (Bruchfestigkeit 6183 at, Fließgrenze 4215 at) und Rundeisen (Bruchfestigkeit 3998 at, Fließgrenze 2820 at) vorgenommen („Ingeniören“ 1908, Seite 127), aus welchen er schließt, daß man, wenn die eingegossene Länge des Eisens genügend ist, die Knoteneisen bis zur Bruchgrenze belasten kann, während man mit den Rundeisen niemals über die Fließgrenze kommen kann (Eisen ohne Haken vorausgesetzt).

Platten mit 0·2—0·7% Armatur zeigten eine um 36—40% höhere Bruchlast, wenn sie mit Knoteneisen armiert waren, statt mit Rundeisen, aber die Rißbildung trat bei derselben Belastung ein.

Für die laufende Kontrolle der Eisenbetonbauten werden am meisten kleine Balken verwendet. Die Länge ist 200 cm, die Höhe 6 cm, die Breite 9 cm und die Armierung 2 Stück 7 mm Rundeisen mit Haken versehen und so eingelegt, daß der Abstand von der Unterseite des Balkens bis zur Mitte der Eisen 1 cm beträgt. Wenn die Balken 28 Tage alt sind, werden sie mit 1·8 m Spannweite in der Mitte belastet und die Bruchlast P soll dann wenigstens $4{\cdot}5\,\sigma_b$ betragen, wenn σ_b diejenige zulässige Betondruckspannung ist, mit welcher der Unternehmer bei der Dimensionierung des Bauwerkes gerechnet hat.

IX 1 d

VERSUCHE MIT EISENBETON-KONSTRUKTIONEN IN HOLLAND.

Mitgeteilt von **S. J. Rutgers** in Rotterdam.

I. Versuche auf Durchbiegung.

A. Versuche mit statisch unbestimmten Konstruktionsteilen.

1. Prüfung von 21 Bogen des Eisenbahnviaduktes aus Eisenbeton in Rotterdam mit Spannweiten von 7·5 bis 20 m und von vier Bogenbrücken über die Eisenbahn Maastricht-Aachen in Limburg mit Spannungen von 20 m. Die gemessenen Durchbiegungen wurden mit den berechneten verglichen. (Vgl. „De Ingenieur" Nr. 25 und 45 von 1907 und Nr. 23 von 1908.)

2. Prüfung einer Laufbrücke über die „Lusthofstraat" in Rotterdam mit einer Spannweite von 29 m. Außer Durchbiegungen wurden auch Formänderungen gemessen mittelst acht Spannungsmessern, System Manet-Rabut. (Siehe „De Ingenieur" Nr. 6, 1902.)

3. Prüfung von zwei zu diesem Zwecke eigens hergestellten Konstruktionselementen der Brücke über den „Hoogen Boezem" in Rotterdam mit einer Spannweite von 6·55 m. Außer Durchbiegungen wurden auch Formänderungen gemessen mittelst sechs Spannungsmessern, System Schroeder van der Kolk.

4. Behufs des Kasernenbaues in Ede wurde eine von der Firma F. J. Stulemeyer hergestellte Platte erprobt, welche auf vier Stützen mit Zwischenräumen von 3·31 m Mitte bis Mitte aufgelegt war. Die Platte war 1 m breit, 0·1 m dick und armiert mit 10 Stäben von 10 mm. Die Durchbiegungen wurden gemessen und die Probe bis zum Bruche durchgeführt.

B. Versuche mit flachen Platten und Balken rechteckigen Querschnittes.

1. Zu den ältesten Versuchen gehören die von Herrn Tutein Nolthenius seit 1894 angestellten. Es wurden von ihm Serien von Platten geprüft, und zwar: Serie a: 13 Platten, 2 m lang, 0·40 m breit, 0·05 m dick, mit einer Tragweite von 1·90 m. Serie b: 15 Platten, 0·82 m lang, 0·47 m breit, 0·03 m dick, mit einer Tragweite von 0·68 m. Serie c: 10 Platten, 2·10 m lang, 0·40 m breit, 0·05 m dick, mit einer Tragweite von 2 m. Die Belastung erfolgte mittelst zweier konzentrierten, symmetrisch zur Mitte angebrachten Lasten. Der Lastenabstand betrug für Serien a und c 25 cm, für Serie b 17 cm. Die Armierung war verschieden, sowohl in Länge, als in Breiterichtung, ebenso die Beschaffenheit des Betons und die Dauer der Erhärtung. Serie c war mit doppelter Armierung versehen. Die Platten wurden bis zum Bruch belastet, während die Durchbiegungen gemessen wurden. (Siehe „Zeitschr. des Österr. Ingenieur- und Architektenvereins", 1896/97.)

Von Herrn L. A. Sanders wurden seit 1896 eine Reihe von Versuchen angestellt, und zwar:

2. Etwa 40 Biegeproben mit Balken von 2 m Tragweite und Dimensionen von $10 \times 15{\cdot}2$ c. M. bis 10×19 c. M. Die Armierung wechselte zwischen $1^1/_4{}^0/_0$ und $2^1/_2{}^0/_0$. Von jeder Gattung wurden acht Stück geprüft mit verschiedener Beschaffenheit des Betons und verschiedener Dauer der Erhärtung. Die Belastung erfolgte in der Mitte und wurde bis zum Bruch durchgeführt.

3. Für die auf Rechnung der Militärverwaltung ausgeführten Bauten wurden zwei Platten erprobt: eine zu Gorinchem mit einer Tragweite von 4·20 m, einer Breite von 0·80 m, einer Dicke von 0·12 m und $1^1/_4{}^0/_0$iger Armierung und eine in Amsterdam mit einer Tragweite von 3·75 m, einer Breite von 1 m, einer Dicke von 0·14 m und $1^1/_2{}^0/_0$iger Armierung. Für beide Platten war die Dosierung des Betons 1 : 2 : 2 in Volumeneinheiten. Der Bruch trat in der Mitte auf.

4. Zur Beobachtung des Einflusses von Bügeln wurden zwei Platten geprüft mit folgenden Dimensionen: Tragweite 10 m, Breite 0·50 m, Dicke 0·34 m, Armierung 10 Stäbe von 18 mm Durchmesser. Die Platte mit Bügeln trug eine $10^0/_0$ höhere Belastung, als die ohne Bügel.

5. Bei einer Prüfung von zwei Platten, breit 1 m, mit 0·46 m Stützweite und einer Dicke, abwechselnd von 6 cm nahe an den Stützen bis 9 cm in der Mitte, wurde ein hölzerner Klotz von 10 × 10 cm Grundfläche durch die Probeplatte bei einer Belastung von 4950 kg hindurchgedrückt, nachdem zuerst Risse parallel zur Richtung der Stützweite aufgetreten waren.

6. Eine Platte mit einer Stützweite von 5·94 m, einer Breite von 1·20 m und einer Dicke von 25 cm, armiert mit 10 Stäben von 16 mm, wurde gleichmäßig belastet, wobei die Durchbiegungen gemessen wurden. Bei einer Belastung von etwas über 2000 kg trat der Bruch ein.

7. Für einen Bau der Militärverwaltung zu Zuidwykermeer wurden drei Platten mit doppelter Armierung versucht. Die Dimensionen der Platten waren: Länge 13 m, Breite 1 m, Dicke 0 25 m. Die Armierung bestand aus 16 Stäben von 16 mm Durchmesser sowohl an der oberen als an der unteren Seite. Die Stützen befanden sich in einer Entfernung von 5 m von Mitte zu Mitte, wobei durch Anbringung einer Belastung auf den frei vorragenden Enden negative Momente über den Stützen hervorgerufen wurden.

Die drei Platten waren von denselben Dimensionen und gleicher Beschaffenheit, mit der Ausnahme, daß eine dieser Platten ohne Bügelarmierung war und die beiden anderen 32, bezw. 64 Bügel pro m² enthielten. Der Bruch entstand jedesmal zuerst nahe an einer der Stützen bei Belastungen, welche sich verhielten wie 2·03 : 1·07 : 1. Es stellte sich dabei heraus, daß die Platte ohne Bügelarmierung die größte und die mit 64 Bügeln die kleinste Bruchlast aufwies. (Für alle diese Versuche vgl. „Het Cement-Yzer in theorie en practyk“ von L. A. Sanders, S. 251 bis 319; siehe auch die Bemerkungen von Dr. F. v. Emperger in „Beton und Eisen“ 1903, S. 262 und 263.).

8. Seitens der „Holländischen Eisenbahn-Gesellschaft“ wurde, für einen Tunnelbau unter dem Rangierbahnhof zu Watergraafsmeer, eine Platte erprobt mit einer Spannweite von 6·825 m, einer Breite von 1 m und einer Dicke von 0·65 m. Die Hauptarmierung bestand aus 12 Stäben von 30 mm Durchmesser, während überdies, sowohl in horizontaler als in vertikaler Richtung, Hilfseisen zur Aufnahme von Schubspannungen angeordnet waren. Mittelst zehn Spannungsmesser, System Schroeder van der Kolk, wurden die Formänderungen in der Mitte der Spannweite in fünf

verschiedenen Höhen gemessen. Die Platte wurde bis zum Bruch belastet, während die Durchbiegungen regelmäßig aufgezeichnet wurden.

Die beobachteten Spannungen wurden mit denen verglichen, welche durch Berechnung unter Vernachlässigung der Zugspannungen im Beton gefunden wurden, und mit den Spannungen, wie sie nach der Methode Sanders berechnet wurden (vgl. „Beton und Eisen“, Heft 11, 12 und 1 von 1906/1907 und „Het Cement-Yzer in theorie en practyk“ von L. A. Sanders, Seite 319—336).

9. Von Herrn A. C. C. G. van Hemert wurden Biegeproben gemacht mit 4—5 m langen Balken von 12×18 cm. Mittelst vier Spannungsmessern wurden die Formänderungen gemessen, wobei auch der Einfluß wiederholter Belastungen und Entlastungen beobachtet wurde (vgl. „De Ingenieur“ No. 23, 1904).

C. Versuche mit $\top$ Balken.

Von Herrn L. A. Sanders wurden nachfolgende Versuche angestellt (vgl. dessen oben erwähntes Werk):

1. Vergleichende Versuche mit $\top$ Balken und $\bot$ Balken. Vier Balken, deren Flansche 0·50 m breit, 0·06 m dick und deren Körper 0·30 m hoch und 0·20 m breit war, mit 4 Stäben von 20 mm armiert, wurden bis zum Bruch belastet, während die Durchbiegungen aufgezeichnet wurden. Zwei der Balken wurden in $\top$ Form und zwei in $\bot$ Form hergestellt und erprobt.

2. Für den Kasernenbau zu Gorinchem wurde ein $\top$ Balken erprobt, dessen Flansche eine Breite von 1·40 m und eine Dicke von 0·08 m, der Körper eine Höhe von 0·52 m und eine Breite von 0·20 m hatte. Die Stützweite betrug 7 m. Die Armierung bestand aus 5 Stäben von 20 mm. Der Balken wurde bis zum Bruch belastet, der in der Mitte auftrat, während die Durchbiegungen regelmäßig registriert wurden.

3. Unter Leitung der Militärverwaltung zu Amsterdam wurde ein Balken erprobt mit einer Flanschenbreite von 1 m, einer Dicke von 0·17 m, 0·33 m Körperhöhe und 0·30 m Körperbreite. Der Balken war mit 8 Stäben von 30 mm armiert und hatte eine Spannweite von 4·90 m. Die Durchbiegungen wurden gemessen, bis der Bruch 0·85 m von einer der Stützen entfernt eintrat.

4. Von Seiten des Stadtbauamtes wurde im Haag ein 4·16 m langer Balken mit 1 m breiter und 0·10 m dicker

Flansche und 0·30 m hohem, 0·20 m breitem Körper, armiert mit 4 Stäben von 25·4 mm, erprobt. Die Belastung erfolgte mittelst zwei konzentrierter Lasten, während die Durchbiegungen an drei Stellen regelmäßig aufgezeichnet wurden. Der Bruch trat in der Nähe der Lasten ein.

5. Seitens der Firma van Waning & Co. wurde für Zwecke der „Technischen Hochschule“ in Delft ein Balken erprobt mit 2·08 m Flanschenbreite, 0·12 m Flanschendicke, 0·23 m Körperhöhe und 0·20 m Körperbreite; Spannweite 6·25 m, Armierung 8 Stäbe von 25 mm Durchmesser. Die Durchbiegung wurde an fünf Stellen gemessen und die Belastung bis zum Bruch durchgeführt, der nahe bei einer der Stützen eintrat.

II. Versuche auf Druck.

Seitens des Herrn L. A. Sanders wurden 36 Druckproben gemacht mit Prismen von 17×17×17 cm und von 17×17×30 cm, die nur mit verschiedenen Querarmierungen versehen waren. Zweck der Versuche war, den Einfluß der Querarmierung zu beobachten, welche wechselte von 0·7% bis 4·2% vom Volumen der Probestücke (vgl. „Het Cement-Yzer“, Seite 362—369).

III. Versuche auf Abscherung.

Seitens des Herrn L. A. Sanders wurden 12 Versuche angestellt, wobei runde, mit scharfgängigem Schraubengewinde versehene Stäbe in Betonwürfeln von 30×30×12 cm eingebracht waren. Die Stäbe, die aus den 12 cm dicken Betonprismen hervorragten, wurden durch dieselben hindurchgedrückt, wobei die dreieckigen Zwischenräume des Gewindes mit Mörtel gefüllt blieben, so daß in der Tat eine Abscherung stattfand.

Herr A. C. C. G. van Hemert hat die Größe der Schubspannung abgeleitet aus Torsionsproben mit Betonzylindern von 20 cm Durchmesser und gleicher Höhe. Die Enden der Zylinder bildeten Würfel von 20×20×20 cm, an denen das Torsionsmoment angreifen konnte (vgl. De Ingenieur Nr. 31, 1904).

IV. Versuche auf Adhäsion.

Seitens des Herrn L. A. Sanders wurde eine Anzahl Versuche gemacht, wobei 12 cm lange, in Würfeln von 10×10×10 cm

angebrachte Stäbe verschiedenen Durchmessers durch den Beton durchgedrückt wurden.

Herr A. C. C. G. van Hemert leitete die Größe der Adhäsionsspannung aus Torsionsversuchen ab, wobei ein Stab von 25 mm Durchmesser in der Mitte eines Betonwürfels von 20×20×20 cm angebracht war, während die herausragenden Enden eingespannt und der Würfel durch ein Torsionsmoment gedreht wurde. Aus der Größe des Torsionsmomentes, bei welchem sich der Würfel zu drehen anfing, wurde von ihm die Adhäsionsspannung berechnet.

V. Versuche bezüglich Ausdehnung und Wärmeleitung des Betons.

Von Herrn A. C. C. G. van Hemert wurden nachfolgende Versuche angestellt:

In einem 3 m langen, 18 cm hohen und 12 cm breiten Betonbalken wurden Löcher ausgespart, welche bis in die Mitte des Balkens reichten. In diese Löcher wurde Quecksilber gegossen, in welches Thermometer gestellt wurden, worauf die Löcher mit Mörtel in der Weise ausgefüllt wurden, daß auf allen Seiten ungefähr 6 cm Beton war. Der Balken wurde in einem dazu eingerichteten Gebäude von 10 × 4·25 × 2·90 m aufgestellt, in welchem die Temperatur allmählich erhöht wurde, so daß die Thermometer von 26^0 auf 34^0 Celsius stiegen. Dabei wurde die Längeänderung der Balken gemessen.

Behufs Beobachtung des Leitungsvermögens wurden Balken von gleichen Dimensionen durch eine der Wände des obenerwähnten Gebäudes geführt. In der Achse der Balken wurden mit Zwischenräumen Thermometer angebracht. Außerhalb des Gebäudes wurde der Balken durch ein Koksfeuer erhitzt, während die Thermometer regelmäßig abgelesen wurden (vgl. „De Ingenieur“, 1904 Nr. 31).

VI. Versuche über Haarrisse.

Von großer Wichtigkeit sind diejenigen Versuche, welche gemacht wurden, um die Anwesenheit von Haarrissen zu zeigen. Dabei wurden Balken einem biegenden Momente ausgesetzt und zwar so, daß die gezogene Seite sich oben befand. Bei der von Herrn P. A. M. Hackstroh angewandten Methode wurde dann bei einem bestimmten biegenden Momente die obere Seite des Balkens reichlich mit einer verdünnten Anilinlösung bestrichen. Nachdem die Anilinlösung in den Beton gedrungen war, wurde der Balken entlastet,

wobei die Haarrisse, welche dem unbewaffneten Auge durchaus unwahrnehmbar waren, sich deutlich zeigten, indem das Anilin nach außen gepreßt wurde. Nach Zerlegung des Balkens konnte beobachtet werden, wie weit die Anilinfarbe in die Risse eingedrungen war.

Diese Methode ist von Herrn A. C. C. G. van Hemert noch verbessert worden, der während der Belastung der Balken auf denselben Streifen von mit Wasser verdünnter Anilinfarbe zog, welche fortwährend feucht gehalten wurden. Sobald irgendwo ein Riß entsteht, sieht man die rote Flüssigkeit seitwärts ausfließen und man kann das Moment aufzeichnen, bei dem solches stattfindet. Am Ende des Versuchs wird überdies die ganze obere Seite nach der Methode des Herrn Hackstroh mit Anilin gesättigt. In dieser Weise gestattet schon ein einziger Versuch einen Überblick zu der Frage, bei welchen Momenten Haarrisse entstehen und zu welcher Tiefe dieselben eindringen.

VII. Versuche über den Einfluß von Seewasser.

Unter Leitung des Herrn H. Wortman wurden an der Landungsbrücke zu Ymuiden vier Balken aufgehängt. Dieselben waren 10 cm hoch und 15 cm breit und mit 3 Rundeisen von 10 mm armiert. Die Aufhängepunkte befanden sich in einer Entfernung von 2 m, während in der Mitte ein Gewicht angebracht war, welches stets unter Wasser blieb und so eine konstante Kraft von 400 kg ausübte. Die Balken selber waren bei Ebbe und Flut abwechselnd in der Luft und im Wasser. Die Zusammensetzung des Betons war 400 kg Zement pro m^3 Beton. Die berechnete Eisenspannung betrug gut 1200 kg pro cm^2 unter Vernachlässigung der Zugspannungen im Beton. Nachdem die Balken zwei bzw. drei Jahre in belastetem Zustande gehangen hatten, zeigte sich bei der Zerlegung das Eisen, von einigen vereinzelten oberflächlichen Rostfleckchen abgesehen, völlig rostfrei. Die Zerlegung der beiden ältesten Balken geschah in Gegenwart des Ausschusses zur Aufstellung von Normen für Eisenbeton in Holland.

VIII. Versuche über den Einfluß von Öl und Teer.

Von Herrn Wouter Cool wurden Versuche angestellt mit Beton-Körpern von $20 \times 5 \times 5$ cm, verschiedener Beschaffenheit, in welchen Rundeisen angebracht waren, die aus dem Beton hervor-

ragten. Nachdem die Körper während ungefähr 2 Jahren in Wassergas-Öl, resp. Wassergas-Teer aufbewahrt waren, wurde die Kraft ermittelt, welche nötig war, um die Stäbe aus dem Beton herauszuziehen. Aus Parallelproben mit Betonkörpern, welche in der Luft aufbewahrt worden waren, stellte sich heraus, daß die Haftfestigkeit durch die Einwirkung von Teer und in noch höherm Maße durch die von Öl vermindert war.

Versuche zur Kontrolle der Ausführung von Eisenbeton-Konstruktionen.

Bisweilen wird zur Beurteilung einer ausgeführten Eisenbeton-Konstruktion eine Probebelastung auf einem Teil der vollendeten Konstruktion vorgeschrieben. Die Dauer der Erhärtung wird dabei in der Regel freigelassen. Die Größe der Probebelastung wird verschieden vorgeschrieben, ebenso wie die zulässige maximale Durchbiegung. So darf z. B. in Rotterdam die Durchbiegung nicht mehr betragen als höchstens $^1/_{800}$ der Spannweite bei einer Belastung von $0{\cdot}80 \times$ dem Eigengewicht $+ 1{\cdot}8 \times$ der Nutzlast.

In einigen Fällen werden außerdem während der Ausführung Druckproben mit dem auf dem Bau benutzten Beton angestellt. Die Probeblöcke haben in der Regel Dimensionen von $30 \times 30 \times 30$ cm.

Bei wichtigen Konstruktionen kommt es vor, daß zur Prüfung besondere Konstruktions-Elemente hergestellt werden, welche so viel wie möglich mit den auszuführenden Werken statisch übereinstimmen. Diese Probestücke werden dann bis zum Bruch belastet, wobei das Durchbiegungsdiagramm aufgezeichnet wird.

IX 1 e

RECHERCHES EXPÉRIMENTALES SUR LE BÉTON ARMÉ EN SUISSE.

Rapport de M. **F. Schüle** à Zurich.

Jusqu'en 1900 les expériences sur le béton armé sont dues à l'initiative privée et ont eu pour but d'éclairer le public technique en faisant ressortir les avantages de divers systèmes. En 1899 la Société suisse des ingénieurs et architectes et celle des fabricants de ciment instituèrent une commission pour l'étude systématique et indépendante du béton armé; en 1905 cette commission fut transformée et prit un caractère officiel, ses membres étant désignés par l'Administration fédérale, l'Association des villes suisses et les sociétés citées plus haut. Le premier but proposé a été la préparation de prescriptions sur le béton armé, basées sur les essais et l'expérience. Les essais jugés nécessaires ont été exécutés au Laboratoire fédéral d'essai des matériaux à Zurich et peuvent être groupés comme suit:

1. Essais sur les matériaux isolés.

a) Fer. Expériences sur la résistance des crochets à l'extrémité des barres de fer rond, pliés à froid ou à chaud suivant des rayons variables.

b) Beton. Détermination de ses propriétés mécaniques suivant la nature du sable et du gravier. Le sable et le gravier ont été fournis par les villes suisses, les essais ont été effectués avec deux ciments Portland et trois dosages différents, béton gâché en con-

sistance plastique et pilonné sous forme de prismes de 12×12×36 cm. Les essais ont eu lieu à 28 jours, 3 mois, 1 an et 2 ans, à la flexion et à l'écrasement; on a fait en outre des mesures d'élasticité.

c) Mortier et béton. Détermination des changements de longueur pendant le durcissement à l'air ou sous l'eau. Les éprouvettes en forme de prismes ont été faites: Pour les mortiers 1. avec 5 liants différents au dosage de 1:0 et 1:3; 2. avec 2 liants différents au dosage de 1 : 1, 1 : 3 et 1 : 5. Pour les bétons avec 2 liants différents au dosage de 150, 300, 450 kg par m³ de sable et gravier.

Deux séries de prismes ont été en outre munies d'armatures. Les essais ont été étendus sur une période de 2 ans

2. Essais de béton armé faits au Laboratoire de Zurich.

a) La plus grande partie des essais ont été faits sur des poutres sollicitées à la flexion; on a observé les charges caractéristiques correspondant aux diverses phases de fatigue, les charges de rupture, l'effet de l'enlèvement de la charge, les variations de longueur surtout dans la zone comprimée, en vue de fixer d'une manière sûre la position de l'axe neutre, la flexion au milieu de la poutre.

La charge a été appliquée de diverses façons:

I. Charge unique au milieu.

II. Charge agissant en 2 points symétriques.

III. Charge agissant en 7 points répartis sur la longueur totale.

IV. Charge dysymétrique agissant en 4 points répartis sur une moitié de la longueur. Les poutres étaient soit de section rectangulaire, soit de section en **T**.

Les armatures étaient formées de barres droites et de barres relevées à leurs extrémités, sans et avec étriers.

En calculant le pourcentage de métal par rapport à la section de béton au-dessus de l'axe de l'armature dans les poutres à section rectangulaire, et par rapport à la section de la nervure prolongée jusqu'en haut, au-dessus de l'axe de l'armature dans les parties à section en **T**, les essais ont porté sur les pourcentages suivants: Poutres à section rectangulaire: jusqu'à 4,91% de la

section de béton au-dessus du centre des armatures. Poutres à section en **T**: jusqu'à 4·33 % de la section de béton de la nervure, au-dessus du centre d'armature.

b) L'action d'une charge concentrée sur une plaque armée a été déterminée à l'aide d'essais 1. sur des plaques carrées de 1,00 m d'ouverture libre appuyées soit sur les quatre côtés, soit sur deux côtés, pourcentage des armatures 0·77 et 0·43 % dans les deux sens et 1,54 et 0,86 % dans un sens seulement; 2. sur des plaques rectangulaires de 1·00 sur 1·50 m d'ouverture libre, appuyées soit sur les quatre côtés, soit sur les deux plus longs côtés; pourcentage des armatures:

0·59 %	en	travers	et	en	long	
0·33 %	„	„	„	„	„	
0·77 %	„	„	„	0·30 %	en	long
0·43 %	„	„	„	0·17 %	„	„

c) La répartition de la charge suivant la largeur d'une plaque sollicitée à la compression par une force appliquée sur une largeur égale à l'épaisseur de la plaque a été étudiée à l'aide d'essais à la compression sur des prismes de 1·00 et 0·50 m de hauteur et de largeur, allant de 0·12 à 0·96 m; on a mesuré les déformations en plusieurs points de la largeur sur la section médiane. Quelques plaques ont reçu une armature transversale, les autres étaient en béton non armé.

d) Essais de mâts de section tronconique creuse en béton armé. Les mâts étaient découpés dans des poteaux de ligne électrique; l'armature a comporté un pourcentage de 0.57 à 4·36 % de la section de béton au milieu de la portée.

e) Essais à la compression de colonnes avec armature longitudinale et avec frettes. Il s'agit d'essais isolés; l'étude systématique des colonnes ayant été entreprise dans divers laboratoires étrangers.

3. Essais de constructions terminées en béton armé.

Ces essais ont été entrepris lors de la réception de diverses constructions et ont consisté dans la mesure de la flèche en de nombreux points de la construction pendant l'application de la charge; ces essais ont permis de déterminer le degré d'encastrement et de continuité des poutres principales.

Essais usuels de contrôle du béton armé.

Les cahiers des charges prescrivent l'essai des fers à la traction; pour le béton le contrôle comprend l'essai normal du ciment Portland à 7 et 28 jours suivant les prescriptions suisses, l'essai de séries de cubes ou de prismes (généralement 4) à 28 jours; les cubes ont 16 cm de côté, les prismes une section carrée de 12 cm de côté et 36 cm de longueur. Ces derniers sont soumis à un essai à la flexion, les moitiés subissent l'essai à l'écrasement entre des plaques d'aciers placées en croix et de 12 cm de largeur.

L'importance de ces essais est caractérisée par le fait qu'en 1908 le Laboratoire de Zurich a eu plus de 500 sortes de béton à essayer. Les résultats obtenus montrent une amélioration croissante de la qualité du béton par un dosage judicieux du sable et du gravier.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

IX2

REINFORCED CONCRETE STRUCTURES. MEASURE OF THE DEFORMATIONS OF STRUCTURES UNDER SERVICE CONDITIONS.

Report by M. **Charles Rabut**, Paris.

Appendix to the Committee-Report on Reinforced Concrete.

Translated from the French by A. R. Liddell, Charlottenburg.

The Sub-Committee on Reinforced Concrete has asked us to present to the Congress a report on the experimental study of existing structures.

The object of this report is not to give a general summary of the studies undertaken up to the present and of the results obtained, which appears premature.

We simply propose to demonstrate the utility of these studies and the interest which the International Association has in according its moral support to those of its members who may chance to be in a position to undertake them.

The rules for building in reinforced concrete, which have been formulated in the different countries, whether by the governments or by associations of engineers and architects, have, as far as possible, been brought into connection with laboratory researches in regard to the deformation of concrete and steel, first under individual, and then under combined strain, and the formulae shown by the strength-calculations to be desirable tend to represent the laws of this deformation.

Now, in the laboratory researches, the samples operated upon are of simple form, and the endeavour is made to place them under perfectly definite and known test conditions.

On the other hand, in existing structures the forms of the various parts are more complex, and, in particular, the manner in which each of them is stressed (distribution of the loads, degree of firmness of fixing of the parts, etc.), is à priori unknown; its exact determination would entail calculations of so complex a nature, that their making is in general not to be thought of, and the designer contents himself in this respect with hypotheses the simple nature of which contrasts strangely with the minuteness that is usually introduced into the study of designs of reinforced concrete structures.

Again, an essential element of these calculations is the exact knowledge of what is called the coefficient of equivalence of the metal to the concrete. The rules given for its determination as a function of the rigidities of the metal and of the concrete respectively, and of the number and diameters of the trussings etc., have very rightly been considered doubtful even by those who framed them. Admitting that laboratory experiments, on which the framers of these take their stand, have been made with all desirable precision, they have not been sufficiently numerous to establish the proposition that the coefficient in question depends solely on the quantities as a function of which it is sought to be expressed.

Finally, admitting that this coefficient on the one hand, and the manner of stressing each piece on the other were sufficiently well determined, the limits which are imposed on the deformation of the concrete and on that of the metal in the reinforced concrete structures must, considering the actual state of our knowledge, be looked upon as rather arbitrary. Of this no other proof is needed than the contemplation of the considerable differences attributed to these limits in the rules of the different countries.

On these three grounds it is thought to be necessary at least to supplement the results, which laboratory experiments have been able to furnish, by measurements made on structures in actual work.

Only by this means will it be possible to take account of the manner of stressing of the parts of structures of a given type, with the view to its adoption as a basis for the calculations for other structures of analogous types to be designed.

We shall only be able to arrive at a knowledge of the true coefficient of equivalence in a given structural part by means such

as these, and, with due knowledge of its signification, to sanction its use in further designs.

Only by this means, finally, shall we get to know the values really attained by the local deformation of the concrete and of the steel in structures that have admittedly shown themselves strong enough under service conditions, and be in a position to lay down precise limits which can be conceded to them in the designs of similar structures.

Reference may suitably here be made to the particular cause which renders these limits specially indefinable in the case of structures subject to moving excesses of load, namely the increases of stress due to the rapidity of the application of the excess load. The conditions under which the laboratory experiments can, in this respect, be made are evidently widely removed from those which are to be met with in structures under service conditions, and it is only by working directly on these that a precise valuation of the dynamic effects can be arrived at.

The application of the experimental method to buildings under service conditions has been practised for 15 years on metallic structures; it has shown the insufficieny of the indications given by purely theoretical calculations as far as the representation of the laws of the real deformation is concerned, and enables important progress in the distribution of the material to be made.

Reinforced concrete structures appear destined to benefit by the method to a still greater degree on account of their greater complication.

Such are the reasons which lead us to think that the Association would be doing useful work in encouraging and facilitating researches of this kind.

Another consideration may be brought forward in support of our thesis.

We have called attention in the foregoing to the divergencies which exist in the different countries in regard to reinforced concrete; if the investigations undertaken for the improvement of the rules be carried to a successful conclusion under the auspices of the Association, this will provide a good ground for the introduction of corrections into these rules, which will render them less dissimilar, and bring about uniformity so far as differences of manufacture in the different countries will admit of it. The

Association will thus exercise a useful influence in the direction marked out for it by its own articles.

What form should its intervention take in the matter now occupying our attention?

It does not seem to follow that it should give to the work in question, financial support which would not otherwise be forthcoming.

But it can give its moral support to the experimental study of structures under service conditions by declaring that it considers such study useful and conducive to the ends which it is its mission to pursue.

Besides, it can in certain cases facilitate these by, where necessity, making representations to competent authorities, so as to obtain their authorisation and even their active cooperation where the circumstances are such as to justify it. This intervention would be called forth at the request of one member of the Association who might demonstrate the utility of certain experiments undertaken by himself or others and the necessity of having them authorized, assisted, or subsidized by the competent authorities concerned.

We conclude, therefore, with the hope, that the Congress will give the matter its favourable consideration in this sense.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

V^TH CONGRESS, COPENHAGEN 1909.

IX 3

CASUALTIES IN REINFORCED CONCRETE BUILDING.

By **Dr. Fr. v. Emperger**, Vienna.

Appendix to the report of the Reinforced Concrete Committee.

Translated from the German original by A. R. Liddell, Charlottenburg.

For the formation of a correct judgement on this question, suitable statistics are wanting. It will not do to form our opinions from isolated severe accidents. The greatest disasters of this kind, as for instance those met with on the sea, sink into insignificance in comparison with the accumulated totals of those comprizing every-day occurrences. There is an example lying nearer to us, which gives better expression to this. According to the lists of the Workmen's Union for Iron Bridge and Iron House Buildings in the State of Illinois, the number of deaths in 1905 were as many as 26, that of men incapacitated for work reaching the same figure, and that of the slightly injured amounting to 80, out of a membership of 1350 workmen, that is to say in all about $10^0/_0$. This figure rose in 1906 to 156 cases or $12^0/_0$, a circumstance which was attributed to excessive haste in the execution of the work. In view of these appalling figures we must allow that we have no idea of the amount of the blood-tax which modern buildings demand, nor of the waste of national property represented by carelessly erected buildings that have fallen in. We must say to ourselves then, that a conscientious scheme for the prevention of accidents must take statistics of casualties of this kind as its main basis, and such occurrences are in a high degree promoted by the hushing-up methods hitherto employed, since science

and practice do not get the chance of applying the lessons that are to be learnt from them.

As the first step in this direction attention may be called to the report of Rutgers: "Bauunfälle in Holland", which was presented to the "International Committee for Reinforced Concrete"[1]) and contains material of great value. These endeavours have obtained official support in Switzerland only.

In recognition of this circumstance, I have in my "Handbuch für Eisenbeton" (Handbook for Reinforced Concrete[2]) given the question of accidents on buildings the large amount of space which it deserves, and in the following short description I must make reference to this comprehensive treatise.

The occurrences may be divided into two groups: unpreventable ones in which forces come into play which are not amenable to calculation, and preventable ones, that is to say, such as, in view of the present state of our knowledge of the causes, could with due exercise of caution have been prevented.

Unfortunately an addition will have to be made to these two main groups of a third one which comprises those accidents in which ignorance or thoughtlessness, or even carelessness plays a part — unfortunately an unavoidable evil, with which, in spite of all advances in science, we still have to reckon.

The last-named most dangerous group of building-casualties must lose in extent in the degree in which knowledge on the domain in question increases and extends, and legal and professional means are taken to safeguard this branch of work from ignorance and carelessness. The yearly number of such occurrences is being rapidly reduced.

In illustration of a large number of occurrences of this kind, it will not be out of place to touch shortly upon the so-called concessionaire-system. This is an arrangement which was created by Hennebique, on the basis of which a large plan-manufactory arose in Paris to which several branches were subsequently added, its object being to supply plans to firms which had no drawing-offices of their own. Now, while Hennebique exercised a certain amount of care in the choise of his concessionnaires, so that the

[1]) "Beton und Eisen", 1908, No. VIII and IX.

[2]) See the 2nd number of Vol. IV, Part II, W. Ernst & Sohn, Berlin, which has just appeared.

natural consequences of this separation of design from execution did not under his direction come so clearly to the surface, many of his imitators have overstepped the bounds of all reason. In this manner contractors were set to carry out reinforced concrete structures, who were complete strangers to the work. This has been carried to the greatest lengths by the American companies who have made it their business to sell special iron rods for reinforced concrete. In order to carry out their object, which solely consisted in the selling of large quantities of special iron, the commercial office was supplemented by a designing office, the advice of which, however, was in no case to be allowed to stand in the way of the main object in view. Orders were then obtained promiscuously for buildings, and, on the basis of the firm's own plans which specified the use of special iron, were sublet to any one who presented himself. As far as the original contractor was concerned, the business was concluded with the supply of the specified quantity of iron. It is worthy of note that the greatest number of accidents occurred during a period of inflation in which all firms that treated the reinforced concrete only as an article of commercial speculation, had ample opportunities of doing business, regardless of the question whether their technical officials were able to meet the requirements made on them or not. In view of such phenomena, conscientious reinforced-concrete contractors are in a difficult position. They will never accept more work that they are able to execute with the staff of experienced men at their disposal. A special branch of this kind demands special knowledge, and a firm that employs experienced specialists will necessarily command higher and more regular prices; such an one alone will be in a position to avoid the occurrence of sad experiences such as those above referred to. In this connection see the paper read by Geheimrat Launer (Berlin) before the VIII^th International Congress of Architects in Vienna, 1908. [1])

A. Building Casualties from unavoidable Causes.

In this connection the following causes come in question.

1. **Earthquake.** As is shown by news from San Francisco[2]) and Messina[3]), the material which is the best able to withstand

[1]) "Beton und Eisen", 1908, pag. 209.

[2]) See "Beton und Eisen", 1909, No. 2, page 30: "Die Wiedergeburt von San Francisco" (The New Birth of San Francisco).

[3]) See "Beton und Eisen", 1909, Number 5, page 130: "Der Eisenbeton im Erdbeben von Messina". (Reinforced Concrete in the Messina Earthquake.)

these forces has been found in reinforced concrete. Of course this assumes its application in a suitable form, and reference may in this respect be made to the proposals of the author for earthquake-proof houses.[1])

2. **Inundations.** Here also reinforced concrete is regarded as the most suitable material with which as far as possible to resist these forces of nature.[2])

3. **Dangers from Lightning and Tempest.**

4. **Danger from Fire.**

5. **Power to withstand exceptional blows and explosions.**

Experiment, and with it our knowledge of the power of resistance of reinforced concrete to blows, is a field that now lies completely fallow. We only know, from accidents in which great strength has been developed, that such power of resistance must be very great and that the coherence of the whole structure makes itself favourably conspicuous. I should like to mention a test made on a rail bulkhead by N. Rella & Nephew in a tramway-shed in Vienna, as the only thorough one of its kind with which I amac quainted.[3])

B. Building Casualties from Preventable Causes.

Note worthy in connection with the following is the circumstance that no collapse of a completed building that has been handed over for service is known to have occurred, and that it has always, therefore, been a question of mistakes which proper construction would have been able to prevent, while minor deficiencies in quality were made good by lapse of time.

1. Errors in shuttering.

Schiller wrote: Filled the mould is for the cast;
Industry and art requiting
Will it show itself at last?
Should our hopes be foiled,
Cast and mould be spoiled?
Ah! may be while hopes still flatter,
Mischief strikes those hopes to shatter.

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1) See "Beton und Eisen", 1909, No. 6, page 150.

2) See "Beton und Eisen", 1909, No. 7: ("Brücken, System Visintini".) Bridges, Visintini System.

3) In regard to this see details in the "Handbuch für Eisenbetonbau" (Handbook for Reinforced Concrete Construction), IV, 2. The filling of this gap in our knowledge would be an important task for our testing establishments.

These words conform with that degree of technical skill which, without a closer insight into the action of the forces, only looks towards the result of the work with the feeling of uncertainty. Reinforced concrete has now happily got beyond this stage. The engineer must know how strong he has to make the mould so that it will not break. Building casualties of this kind result either from too weak a shuttering, or from an overburdening of the shuttering in the concreting.

An example of weakness of the centering is supplied by the collapse of the Bridgemann Building in Philadelphia[1]) on July 9th, 1907, and of the Ornament Store in 1906 in Bern.[2]) The latter occurrence resulted in the recent building up of the structure in half scale and the demonstration thereby that, when properly built, it was strong enough for its work. Mention may here be made of two of the greatest catastrophes which have been due to this cause of structural weakness, viz. the collapse of the Bixby Hotel at Longbeach[3]) in California, and that of the mill at Marquette near Lille.[4])

In connection with these we may refer to the accidents which have occurred on the application of the test loads immediately after the removal of the shuttering. These are the collapses of blocks of buildings in Milan[5]) on April 17th 1908, and in Corning, in New York, in 1904.

It may here be observed that the supervision of a reinforced concrete building extends to everything except to the quality and kind of the centering.

It is nothing out of the common, then, when it is further reported, in connection with the case of the above-mentioned Bixby Hotel in California, that for the building of the attic storey, which was not included in the original design, and which was the immediate cause of the collapse, the contractor collected all the old broken timber that was to be found in the house to make the centering. It would accordingly be desirable to publish a number of standard drawings of centerings, such as might supply pattern

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1) "Eng. News", 1907, p. 69.

2) "Schweizer Bauzeitung", 1906, and "Beton und Eisen", 1906, p. 292.

3) "Eng. News" of 6. and 20. December, 1906.

4) "Beton und Eisen", 1908, p. 75.

5) "Beton und Eisen", 1908, p. 180.

and scale to the contractor and to the supervising engineer as to what should be required.

2. Mistakes in the Construction of the Pillars.

Mistakes of this kind in the construction of the vaulting reach back into the history of the time before the rise of reinforced concrete. In the case of beams a defective design may produce a small shift, which interferes with the intended continuity. Numerous examples of this might be cited.

A properly made pillar that is well connected with the beam gives the latter a kind of firm support which is much greater and much surer than that attained by the continuity. Unfortunately current practice and our rules hitherto only take account of the latter. Special experiments with girders firmly fixed at their ends and of framelike arrangement would be necessary in order to clear up this hither so dark a domain so far that we may understand how to avail ourselves of those advantages and to proportion the girders to the capabilities shown by them without waste of iron. As proof of this too little recognized effect, attention may be directed to an interesting case, and to the subsequent reconstruction required. In this case by reason of a mistake in connection with the strength of adhesion and reinforcement, the negative moment in the pillar drew the iron in the upper chord of the girder out of the pillars.

An improperly arranged pillar may be a source of danger. The best known example of this is the collapse of the Hotel zum goldenen Bären in Basle in 1903[1]).

3. Mistakes in Calculation.

In the first place we may refer to a mistake which, well known as it is in iron construction, has not been sufficiently attended to in the domain of reinforced concrete. This is the circumstance that, quite apart from the degree of strain permissible, a certain limit of deflection should not be exceeded.

Among the permissible stresses the adhesive strength, as the foundation of the structural connection, is the one that is most

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[1]) "Schweiz. Bauzeitung" of Aug. 31st. 1901 and May 10th. 1902, and "Beton und Eisen", 1902.

often sinned against. Here experiment, by means of which the quality of an arrangement can be demonstrated, comes to its rights and often shows to what false conclusions the so-called practical sense may in such cases lead. The question as to the proper arrangement of the iron rods in order to obtain the best connection, by means of which alone it is possible to obtain the full value of the iron, or at least to reach the degree of adhesion usually considered attainable, has been on a good many false scents, which have often caused considerable injury to the buildings concerned. As examples of the collapse of buildings which were designed without stirrups may be mentioned that of the railway bridge at Luino over the canal near Bataglia[1]). These phenomena appear — as indeed is everywhere the case — with particular prominence when several faults occur at the same point. Thus, for instance, if a defective stirrup arrangement is combined with inferior (clayey) additions or has been badly mixed (air bubbles,) between stirrups and insertion rods or expansion pieces, the destruction of the girder is a necessary consequence.

The tensile strength of the iron is to-day the safest basis for our calculations. A questionable matter and one to be decided by experiment might be the influence of the tensile strength of the concrete and its shearing strength in the case of ribbed beams. In the absence of exact knowledge of these properties the tendency is only too great, from pure motives of caution, to set up working requirements which go far beyond anything that is necessary, and in contradistinction to the necessary and dangerous properties here referred to, may be designated as national waste. This is particularly the case in regard to the compressive strength of the iron under compression in the upper chord of the girder. In regard to the former, I have repeatedly shown that the reference of the compressive strength of actual practice to that shown in the testing of sample cubes is only possible when the former is almost doubled. The useless arrangement of compression-rods has only recently been inveighed against by Prof. Schule[2]).

In all these cases the testing system shows itself as the only guide for a proper solution of the problems involved, and it should be employed to a greater extent in their elucidation.

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1) "Il Cemento" 1905, p. 457.

2) Nos. XII and XIII of the "Mitteilungen der eidgen. Versuchsanstalt in Zürich".

4. Mistakes in the Production of Concrete.

Occurrences on this domain in the first place comprise those in which the use of bad mixing-water, bad additions or bad cement is involved. While it was formerly looked on as sufficient to have a representative test of the cement made, it is now recognised that this is insufficient in all cases in which special requirements of a high order are made on this material: that what to our practical judgment ought to give a good concrete may be far removed from being a suitable material for reinforced concrete, and that in this connection also the testing system has the last word to say. While the "readiness to make sacrifices" displayed by several of the state departments, and specially by the Deutscher Betonverein, may be gratefully recognized, it must not be forgotten that the building firms in general are not yet convinced of the necessity of this, and make use of it only to a small extent.

Of the influences which can destroy concrete, mention may first be made of faulty production, such for instance as the pouring in of the concrete during heat or frost, or an insufficient adhesion between the successive layers of this material. Finally there comes in question the subsequent destruction of the concrete by sea water, aciduous springs, moor-ground, and such like, as also by means of oil, petroleum, and other fluids. In this domain also the test system is in progress to enlighten us as to the magnitude of the dangers and the means of avoiding them.

5. Destruction of the Iron.

Only the destruction of the iron by rust comes in question here. The cases in which the formation of rust has been furthered by the covering of the iron with poor concrete are extremely rare, since this covering is easy to make. Fraught with danger are the electrical phenomena resulting from potential differences or stray currents, and finally many of the innocent-looking additions made to concrete, such as that of common salt during the occurrence of frost. The latter afterwards becomes hygroscopic and promotes the formation of rust.

In view of these manifold circumstances, which may give rise to accidents in building, doubts were, on the introduction of the reinforced concrete, entertained in many quarters, whether it would be possible to find contractors of so trustworthy a nature

and with their workmen so well organized that they could steer clear of all rocks. The best proof that this is so is the immense amount of work which has already been accomplished. It must further be pointed out that every country which is in possession of a good code of regulations with reference to such work, has been exempt from considerable disasters of this kind, and this to such a degree that the assertion is justified that the methods of prevention of accident hitherto adopted are the right ones.

The treatment of the statistics and of the question of the publication of these occurrences must be described as faulty, and the endeavours to develop and improve the testing system in all the branches here referred to deserve the greatest encouragement; for only in this way, by means of a better recognition of the circumstances of the cases in point, can we put ourselves in a position to prevent them in future and to avoid the methods of construction which have been recognized as bad.

INTERNATIONAL ASSOCIATION FOR □
□□□□□ TESTING MATERIALS □□□□□
□ VTH CONGRESS, COPENHAGEN 1909. □

XVII$_2$

□ ON PRESERVATIVE COATINGS FOR IRON AND □ STEEL, RESUME OF WORK DONE BY THE AMERICAN SOCIETY FOR TESTING MATERIALS.

Presented by **S. S. Voorhees,** Washington D. C.

Until the metallurgist can produce a cheap non-corrosive metal for structural use the integrity of iron and steel structures depends on some form of preservative coating which will prevent corrosion.

Since about one fourteenth of the metal sides of a steel freight car is lost each year by corrosion, and local rusting may destroy the steel members of bridge structures to a point far beyond the limit of safety in a much shorter period, the need for an investigation on preservative coatings is evident.

The American Society for Testing Materials early recognized the importance of such an investigation and in 1902 appointed a Committee on Preservative Coatings for Iron and Steel.

In accordance with the general policy of the Society the Committee which now consists of almost 30 members is composed of producers and consumers. It has been the aim to inlude manufacturers representing all types of preservative coatings.

In general it may be stated that the problem is first to determine the requirements of a satisfactory protective coating, and then to prepare specifications and devise methods and tests which will insure that these requirements are met.

Such investigations will include the causes of deterioration of paint films, a study of the drying and oxidation of oils, the physical condition of the pigment particles, an investigation of the

theory and cause of corrosion, together with a study of the electrolytic dissociation of the pigment with formation of an electrolyte and consequent corrosion of the metal.

Each one of these phases of the general investigation is a problem of magnitude in itself and it has not been possible for the Committee to more than complete the preliminary work. It should be stated here that the members of the Committee have only a limited time for special investigations.

Fortunately other investigators have offered notable contributions to certain phases of the problem and it is confidently expected that the time is not far distant when at least the causes of corrosion and the rust inhibiting and accelerating action of pigments will be definitely settled.

The theory of the drying of linseed oil and the action of dryers is still an open field for research. It has a direct bearing on the deterioration of paint films and requires a searching investigation. A further study of the paint films through physical tests and microscopical examinations will undoubtedly give definite information relative to size and shape of pigment particles.

The requirements for a satisfactory preservative coating may be stated briefly as follows:

For general work it is recommended that the surface be free from dirt, grease and detachable mill scale and rust such as can be removed by the use of hammer and chisel and wire brush. The paint should be as heavy as possible in accordance with satisfactory spreading and working. The time of drying should be as short as possible consistent with durability; excessive amount of dryers should be avoided, but in general the time of drying must depend upon the contingencies in each case.

The undercoat should not be softened or acted upon by subsequent coats of paint.

In general it may be stated that the more impervious the coating is to moisture, air and carbon dioxide, the more durable the coating. As size of pigment particles is a function of permeability it is recommended that the function of fine grinding be carrefully investigated.

The coating should be sufficiently elastic to adhere to the surface through all ranges of contraction and expansion without peeling or cracking.

The coating should further resist the mechanical action of sand, cinders, etc., carried by the wind.

The surface should permit of repainting with a minimum expenditure of time and money in the preparation of the surface.

It is further considered practical to require the coating to be efficient for five years under normal conditions.

To determine the efficiency of the coating it is recommended that tests be in harmony with conditions imposed in actual service as it is useless to prescribe the same tests for all classes of protective coatings.

In general, it is recommended that tests be adapted to demands of service conditions and be divided into the following classes:

1. Actual Service Tests under Normal Conditions to be applied to Full Size Structures and Normal Panel Tests.

Under this head the Committee started a long time service test in June 1906 on part of the new double track deck bridge of the Pennsylvania Railroad over the Susquehanna River at Havre de Grace, Maryland. The bridge is about 4000 feet long, consisting of 18 spans. The trusses are 30 feet deep and the panels 29 feet long. The paint was supplied by 19 manufacturers and applied to 2 continuous spans of the bridge directly over the water, containing 19 panels. Each panel represented one paint test.

In addition to the test of the paint on the bridge proper, panel tests were also made on very carefully prepared steel plates 2 feet by 3 feet, the paint being applied by a most skillful workman, under the most perfect conditions possible. These panels were made in triplicate at 3 spreading rates, 600, 900, and 1200 square feet per gallon of paint. The panels are exposed on the lower chord of the bridge.

Conditions of surface, application, weather, etc. were carefully noted and recorded. Complete analyses of the paints used in the test were made. The paints used in this test, were, in most cases, the representative proprietary coatings prepared for use on iron and steel structures.

The pigments included red lead, graphite, carbon, oxide of iron, white lead, zinc oxide, sulphate of lead, together with clay, silica, silicates and barytes. The oil was in the majority of cases

a pure linseed oil, though in one case rosin or a resinate drier was detected.

The volatile matter was found to be turpentine or naptha or a mixture of the two.

In the set was one heavy asphaltic varnish thinned with naptha.

The result of the inspection made in June 1908 is as follows:

As was anticipated, no marked differences are noted in the majority of cases. As was clearly indicated at the inspection a year ago, the only example of an asphaltum varnish thinned with a petroleum volatile solvent has failed to a marked degree after eighteen months exposure. A carbon paint containing rosin in the oil has developed minute fissure cracks all over the surface. While it is by no means conclusive that this failure is due to the rosin, still it is worthy of note and will be the subject of further investigation.

An example of difference of expansion of red lead under-coat and a carbon final-coat is shown in panel 14. The carbon-coat has cracked badly on the bridge proper in cob-web-like cracks showing the red of the under-coat. On another panel the same final-coat, however, applied both as an under-coat and as a final-coat has not failed in this manner.

It is also interesting to note that one of the pure red lead pigments in straight raw linseed oil shows unmistakable evidence of alligatoring.

High gloss and tenacious film are shown by Panel 1. In this case the pigment consists of oxide of iron, red lead and a carbon black mixed with a varnish containing some gum and thinned with turpentine.

The other panels, as stated in the report of the Sub-Committee show in most cases a marked loss of gloss with minor differences in hardness, tenacity, toughness and elasticity of film. These differences are, however, too slight to warrant an opinion at this time.

There is evidence of rusting to a slight degree on all sections of the bridge due to mechanical injury. These spots have been accurately noted and will be carefully watched at subsequent inspections. In general, however, the paints are affording good pro-

tection and it will require longer exposure to differentiate in the majority of cases.

An inspection made March 26, 1909 confirms the report of last June with no marked changes of note to report. As stated in June, one of the red leads showed unmistakable evidence of alligatoring. In this case the alligatoring is most marked at the spreading rate of 600 square feet to the gallon, but the cracking is apparently superficial. Good protection is afforded, however, by this paint.

In general, most of the paints are affording good protection.

It is impossible to give details of the tests in this paper, but reference is made to reports of Committee E in Proceedings of the American Society for 1906, 1907 and 1908.

To supplement the investigation of Prof. Ladd, of Fargo, North Dakota, in his effort to determine the value of inert and reenforcing extenders when added to white lead and white zinc and other pigments, as compared to pure white lead and white zinc, the Paint Manufacturers Association has started a similar set of panel tests in the smoke laden atmosphere of Pittsburg, Pennsylvania and the moist, saline atmosphere of Atlantic City. The inspection of this latter set of tests is under the supervision of Committee E.

The paints used in this test include pure white lead, pure white zinc, varying mixtures of white lead and white zinc, white lead mixed with sublimed white lead (a basic sulphate of lead), together with calcium carbonate, aluminum and magnesia silicates, barytes, silica, calcium sulphate, blanc fixe and lithopone, used alone and added in varying amounts and combinations to white lead and white zinc.

About 50 formulae each in white and yellow and drab tints are included in this test applied in duplicate to panels of well seasoned and selected white pine, yellow pine and cypress.

The results of the inspection of these panels together with a record of composition of the pigments and conditions of application will be included in the report to be presented to the Society in June 1909. It may be stated that when inspected March 27, 1909, the yellow and drab tints were in better condition than the

white; and that the paints applied to the white pine were in better condition than those applied to the yellow pine and cypress.

The lithopone has failed to a marked degree.

There is undoubted evidence of failure due to checking, cracking and chalking in a number of the pure and combined pigments, but the results at this time do not warrant any definite conclusions except as stated.

A third set of panel tests have been started at Atlantic City to determine the rust inhibiting or accelerating action of certain pigments on steel plates. The details of these tests will be given later under the head of Special Laboratory Tests.

2. Accelerated Tests applied to specially prepared Surfaces and subjected to abnormal Conditions.

Under this head a circular letter was sent to the members of the Committee, requesting them to express their opinion on the following tests:

1. Preparation of paint films.
2. Testing of paint films in situ.
3. Testing of paint films, removed from surface painted.

In the preparation of paint films uniformity should be sought as far as practicable as to:

a) Temperature and time to be allowed for drying.

b) Atmospheric moisture during drying and testing.

c) Exposure to light.

d) Thickness of film both before and after evaporation of volatile thinner and oxydation, and such other conditions as may be found desirable.

In the testing of the paint films in situ the following tests have been suggested:

a) Resistance to mechanical abrasion, as for instance to a stream of sand falling from a standard height;

b) Mechanical penetrability as shown when using a blunt pointed instrument, subjected to increasing pressure;

c) Electrical conductivity, dry;

d) Electrical conductivity, wet, with distilled water;

e) Electrical conductivity, wet, with distilled water, containing a standard amount of saline matter, constituting an electrolyte,

f) Penetrability to water as shown by Dr. Dudley's Gummed Label Test, and such other tests as may be found desirable.

In the testing of the paint films, removed from the surface, the following tests have been suggested:

a) Water evaporation through paint films as indicating penetrability, etc.;

b) Per cent of film soluble in cold water;

c) Elasticity of film;

d) Tensile strength of films with elongation before breaking, and such other tests as may be found desirable.

The replies were in the main favorable to the above set of tests, but as the work developed they seemed to fall more naturally into the class of laboratory tests.

3. Laboratory Tests including Chemical Analysis and Special Physical, Mechanical and Microscopical Examinations.

As these tests can only be of practical value when experience permits of proper interpretation of results, they require careful investigation. From the results so far obtained the indications are that they may give the information desired.

The work of Dr. Allerton S. Cushman of the U. S. Department of Agriculture is of special interest. It was considered of such importance that a joint committee, composed of Dr. Cushman and Dr. W. H. Walker of the Massachusetts Institute of Technology, both of Committee U on the Corrosion of Iron and Steel, and Mr. G. W. Thompson of the National Lead Co., Mr. P. H. Walker of the U. S. Department of Agriculture, and the writer from Committee E, were appointed to investigate the subject.

Dr. Cushman's investigation on the theory of corrosion naturally led to a study of the relative resistance of different steels and their protection against corrosion.

His researches, extending over several years of careful investigation, have stimulated the steel producers to roll a more rust resisting metal. If his theory of the rust inhibiting and accelerating action of pigments is established by service tests, when these pigments are applied as a paint, the life of steel structures will be increased.

I am indebted to Dr. Cushman, chairman of this joint committee for a briet resumee of his investigation which has been condensed as follows:

In the course of certain investigations that he carried on with regard to the causes of corrosions and the methods of preserving iron and steel, it was suggested on theoretical grounds that certain pigments should have an inhibiting effect on corrosion, while others should have a stimulating action.

Since chromic acid and its salts are known to prevent corrosion by rendering the surface of the iron passive in contact with moisture, it was suggested that chrome pigments might be of value as priming coats. Laboratory test, however, with chrome pigments as well as other pigments gave varying results, indicating that the results obtained were due to impurities in the pigment having either stimulative or inhibitive action.

At the suggestion of G. W. Thompson a special set of laboratory tests were made by placing weighed and polished steel plates in a series of wash bottles containing water and the pigment to be tested. Air was drawn through this train for a definite period, two to three weeks, and at the end of that time the plates were washed and brushed clean, dried and weighed. The result of this test indicated whether the pigment should be classed as an inhibitor of rust, or occupy an intermediate zone called neutral or indeterminate pigment or was found to be an accelerator of rust. About 50 pigments were tested in this manner by five independent analysts. From the results obtained 10 inhibitors and 9 stimulators were selected on which concordant results had been obtained by the five analysts. With this data at hand the Paint Manufacturers Association of the United States offered their cooperation for a series of tests on a large scale. Some 600 plates, representing open hearth and Bessemer steel and an especially pure iron were painted under test conditions using the same quality and grade of linseed oil and dryer in each case, the different consistencies being made normal by the addition of pure turpentine as necessary.

In addition to the above sets of tests additional plates were painted with the ordinary paint as specified by various railroad engineers and others. These plates were mounted in wooden frames and exposed to saline atmospheric conditions at Atlantic City,

New Jersey. Although they have been in position only a few months some interesting results are beginning to show and it is hoped that in the course of a year much valuable data will be secured.

As a laboratory test along this line, the following scheme is recommended: Clean steel knife blades are painted with the pigments to be tested, made up as water colors, and applied as a thick coating. After drying the knife blades are placed in contact with moist blotting paper for a period of 48 hours. The pigment is then scraped off and the surface of the steel examined. The corrosion of the different types of pigments can be determined by the appearence of the steel, certain pigments having a marked corroding action while others are actual protectors and no corrosion will be noted. The tests can be made quantitative by weighing the steel before and after the test. The same test can be used by applying the pigment in its normal oil vehicle; after drying it is kept under wet blotting paper for a period of three weeks, when the paint is cleaned off and the steel examined as in the previous case. The results obtained by testing the pigment with an oil vehicle have been found to agree with the results obtained when the same pigment is tested in water suspension. One interesting point seems to develop from these tests, i. e., those pigments which are of themselves conductors of electricity or which in contact with water develop electrolysis invariably have a corrosive action on the surface of the steel.

These observations corroborate the theory that the corrosion is due to what may be called autogenuous electrolysis, which takes place on the surface of the metal. The Cushman-Walker ferroxyl test has shown that iron or steel invariably throws itself into positive and negative nodes when in contact with the corrosive medium, the effect of this being to stimulate the solution pressure of iron at the positive node, thus causing more rapid corrosion. Certain pigments check this action and therefore prove themselves to be inhibitors. It is impossible, however, at the present to interpret the results as sufficient time has not yet elapsed to collect and collate the data.

This theoretical research of Dr. Chushman affords a most valuable ground work for practical investigations. It indicates that preservative coatings for iron and steel may include two distinct

features which may or may not be obtained by one pigment. First an inhibiting under-coat, and second, an excluding final-coat.

An inspection of these steel panels made March 27 shows that the four months exposure is too short a period to throw much light on the inhibiting or accelerating action of these pigments, but it does support the theoretical position of calcium sulphate in showing it to be an accelerator of rust, while as far as can be determined, it seems possible that the chromium resinate applied in oil without any pigment maintains its theoretical position as an inhibitor.

The study of the paint film offers an attractive field for investigation, but its success depends largely on developing a method of removing the film intact from the surface to which it is applied.

Several methods have been used by individual members of the Committee, and in their hands gave satisfactory results. One method is to apply the requisite number of coats to a bond paper sized with a very soluble coating of noodle paste; after the paint is dry the film is floated off by immersion in water.

Another method is to apply the paint to a sheet of tin foil and dissolve the foil in a bath of mercury. Another method is to apply the paint to a slab of a low melting point alloy. The alloy is melted and the film is obtained intact.

The following method has also been used with success: A sheet of ordinary tin plate is thoroughly amalgamated dry with mercury and the excess wiped off; the amalgamation is repeated at the end of twelve hours. The requisite number of coats of paint is applied to the amalgamated surface, and when dry, the film can be removed intact.

In testing the detached film Mr. R. S. Perry of the Paint Manufacturers' Association uses a device which consists of two brass plates provided with pins so that a hole of known area bored through both plates accurately coincides. To the upper plate is attached a glass tube about sixty centimeters long. This tube has sealed into it at a point about three centimeters above its juncture to the brass plate a second glass tube which is inclined to the vertical tube at an angle of 45^0. The instrument is standardized by placing a microscopic cover glass between the plates, clamping them together and adding mercury from a burette into the inclined arm. The vertical tube is calibrated to $^1/_{10}$ cubic centimeter. To test

the film it is clamped between the two plates. Mercury is added gradually from the burette. The pressure is read by the vertical height of the mercury column and the deflection or stretch of the film is measured by the difference between the number of cubic centimeters of mercury added from the burette and the reading on the vertical tube. The strength of the film is measured by the vertical height of the mercury colume when rupture occurs. The vertical tube is provided with a counterpoised float which records the maximum height of mercury column. The mercury on breaking the film makes an electrical contact and rings a bell.

Mr. Perry states that his results indicate that different sized pigment particles give an increased strength to the paint film; he also states that rod-like pigment particles as furnished by asbestos have a reenforcing action and also give an increased strength to the film.

A modification of this instrument has been devised, and while it has not been given a thorough trial, the indications are that it will give addional information on the physical character of the film.

It consists of two aluminum plates with circular openings of known areas placed one above the other as in the first device. To the upper plate is attached a glass burette of 2 mm bore calibrated to $^1/_{100}$ cubic centimeter provided with a three-way glass stock-cock. One outlet is connected with a movable mercury reservoir to furnish pressure. The cock is so arranged that the mercury can be run from reservoir to film, from reservoir to burette, and also so as to give a direct connection between burette and film. By this means the breaking strength of the films is measured by vertical height of mercury column; the stretch of film for any pressure up to breaking point by difference of readings in cubic centimeters, when load is applied, and the elasticity as shown by the permanent set, after any load has been applied, is measured by increased reading of burette in cubic centimeter, when pressure is reduced from point desired to lowest point on burette where readings of volume can be made.

The permeability can also be measured for any medium by attaching a manometer to the top of the burette, introducing the medium into the burette, in place of the mercury, to the pressure desired and noting the time required to restore equilibrium.

It may not be possible by this method to compare directly the results obtained from different paints containing different kinds

and amounts of pigments, as so far it has been impossible to obtain films of comparable thickness, but it felt that valuable data can be obtained after varying conditions of exposure.

A microscopic examination of the paint film attached to a surface gives indication of the bonding effect of the vehicle and position of pigment particles. It is necessary to use a vertical illuminator and the illuminating trains such as are used in metallographic examination of metals.

A reflecting surface can be obtained by dissolving off the upper surface of the oil film, by such solvents as dinitrobenzol and, when necessary varnishing, the individual surfaces of the pigment particles by a reflecting medium as a very thin celluloid varnish.

By this means it is possible to use as high as 1/12 inch oil immersion objective and the illumination, by using an acetylene burner is sufficient to obtain satisfactory negatives at this magnification.

Mr. Wirt Tassin, Assistant Curator of the National Museum, has devised an illuminating train which gives very satisfactory results. It consists of a telescope tube which has a maximum extension of 10 inches and which is mounted in a trunion provided with a set screw so as to permit the tube as a whole to be tilted at any angle. A vertical adjustment is provided for by means of a rack and pinion movement.

In the back of the telescope tube is mounted a bull's eye condenser and at the front is a plain convex lens so that the system as a whole has a focal length of the rear lens of 2 inches and that of the front of $1^{3}/_{8}$ inches.

The rear of the telescope tube also carries a shield on the bottom of which is fastened a slot in which any desired color screen may be placed. Fastened to this shield is also a stiff brass rod on which there is a movable carrier for an acetylene jet. This carrier consists of two pieces of brass tubing brazed together at right angles to each other and each of which is provided with a set screw so that the source of light may be moved up or down, forward or back or turned and set in any position and at any angle with reference to the plane of the rear lens, a method of mounting which permits the use of any portion or all of the flame from the thinnest edge to the fullest width.

The jet is connected by means of rubber tubing with any form of generator. The onehere shown is of the „Drip" type and

is provided with a catch bottle which experience has shown to be desirable.

The microscope is provided with a Bausch & Lomb vertical illuminator having a plain glass reflector which reflects light coming to it through an aperture in the side of the mounting

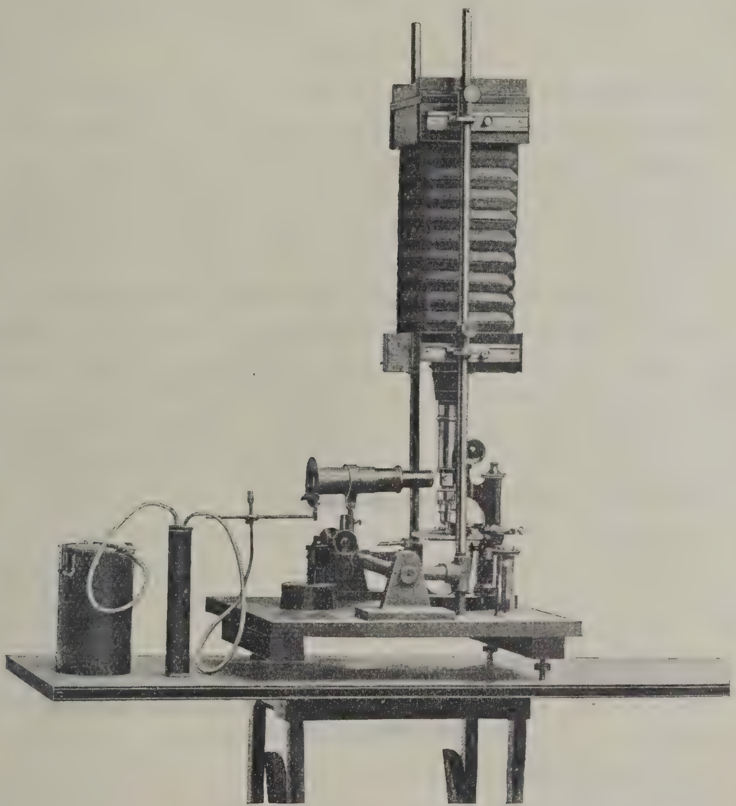

Fig. 1.

Print of Microscope Camera and illuminating Train used by Mr. Wirt Tassin of the U. S. National Museum.

down through the objective upon the object, from which it is reflected through the mircoscope to the eye. Below the illuminator is a "Quick acting nose-piece" which permits of a ready change of objectives without any change of alignment and which experience has shown to be preferable to a "revolving nose-piece". The top

of the tube is so arranged that it slips readily into a light-tight connecting tube carried on the camera.

The length of the tube from the eye-piece to the nosepiece is 16 mm. A photograph of this device with microscope and camera is included.

It is of course simple to use direct illumination for examination of the thin smears of the pigment separated from the vehicle for comparison of the size of the particles etc.

In addition to the tests and investigations already outlined it seemed desirable that a standardization of the tests employed in the examination of raw linseed oil be undertaken, with the aim that when the tests and methods required to determine the quality of linseed oil are satisfactorily established, specifications for this material can be prepared.

A sub-committee has been appointed to undertake this work with Mr. G. W. Thompson of the National Lead Co. as chairman. Four samples of pure oil have been obtained from the crushers, taken under proper supervision.

The tests to be used have been carefully selected and explained, and samples of the oil together with methods to be used have been sent to some 25 analysts.

The following tests are to be applied to these oils:

General: All tests are to be made on oil which has been filtered at a temperature of between 60^0 and 70^0 F. through paper in the laboratory immediately before weighing out, except tests No. 2, Turbidity and Foots, No. 4, Moisture and Volatile Matter, and No. 5, Ash. The sample should be thoroughly agitated before the removal of a portion for filtration or analysis.

1. Specific Gravity.
2. Turbidity and Foots.
3. Breaking Test.
4. Moisture and Volatile Matter.
5. Ash.
6. Drying test on glass.
7. Oxygen and Absorption, Using Lead Monoxide.
8. Acid Number.
9. Saponification Number.
10. Unsaponifiable Matter.
11. Liebermann-Storch Test. Qualitative.

12. Refractive Index.
13. Acetyl Value.
14. Hexabromide Test.
15. Iodine Number.

It is believed that the result of this investigation will enable the Committee to prepare satisfactory specifications for linseed oil.

Summary.

From this resume of the work of the Committee for Preservative Coatings for Iron and Steel it will be noted that no positive recommendations covering the entire field have been issued. It is felt however that the investigation under way will give such certain positive results as will enable the Committe to draw certain definite conclusions.

The paint tests both on the Susquehanna River bridge and the steel panel tests at Atlantic City will throw valuable light on the inhibiting and excluding action of preservative coatings. The tests on wooden panels with single and composite pigments will furnish certain definite conclusions and will simplify the work of the Committee in conducting a confirmatory set of tests.

It can be stated however, that more definite conclusions will be obtained by the middle of the summer, when report is made to the American Society at the Annual Meeting in June.

POSTSCRIPTUM.

The report just presented to the American Society at their Annual Meeting (Atlantic City N. J., June 29 — July 3) did not include as definite conclusions as was anticipated, and does not add materially to data contained in the above paper.

This is due to the fact that the time of exposure of steel plates at Atlantic City is too short to give any actual data, and while the pure white lead and white zinc paints on the wooden panels at same place have chalked more than some of the composite paints it has not been possible for the Committee to make the careful specialized inspection, necessary for a fair comparison of all the paints exposed.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

XVII3

A STUDY OF RUST-PREVENTING PAINTS FOR METAL SRUCTURES.

By **Em. Camerman,** chef du Service d'Essais des Chemins de Fer de l'Etat Belge, Brussels.

Translated from the French by H. Borns, London.

A Report presented to the Zürich Congress by Mr. Valat, Ingénieur en chef à la Compagnie de l'Est français, and my own experiments on several paints, which had recently been advertised, tend to show that poor results are obtained with the following rust-preventing paints:

With paints prepared with a mixture of linseed oil and of essence of turpentine. With paints prepared with tar or its derivatives.

With zinc white paints (enamels).

With paints containing sulphate of barium.

With paints in which manganese resinate forms the siccative.

With zinc sulphide paints.

With lithopone colours (mixtures of zinc sulphide and barium sulphate).

With a pure linseed oil paint which developed blisters.

These poor results will be understood, when we consider the difficulties that the rust-preventing coating should meet. I will enumerate these difficulties.

1. The coating may be wanting in thickness from the very moment of its application, or at least after having dried.

It will be conceded that, other things being equal, a thin coating will not resist so long the incessant bombardment by the

particles of atmospheric dust and will not remain so impervious, as a thick coating.

Thus a paint containing 50% of essence of turpentine is very fluid. It spreads to a much finer film than a paint prepared with boiled linseed oil, which forms a relatively viscous product. The former coating moreover is further reduced in thickness by the volatilisation of the whole of its essence of turpentine, which constitutes half of its volume. The great influence of such mixtures which comprise volatile constituents is evident.

Almost all the tar paints, which generally consist of some pitchy, more or less dry material, dissolved in an essential oil, may be classed with this series of defective paints. The essential oil is to evaporate, and the paint to dry in this way; which will necessarily leave the final coating much weakened.

2. The coating may gradually diminish in thickness. In addition to their solvents the tar paints themselves slowly and gradually give off their volatile constituents. There result hollow spaces, shrinkages, and consequently thin, weak spots, and even fissures.

3. The coating, although satisfying the conditions as to thickness, may be wanting in elasticity. It is thus again with preparations of dry pitch and essential oils.

The dried linseed oil on the contrary forms a soft, elastic pellicle which has often been compared to leather.

4. The coating may lack hardness and not be able to resist the impact of the dust particles, that is to say, it may not wear well. The two qualities, elasticity and hardness, may at first thought appear contradictory. But the two qualities are quite compatible if we mingle a powder of hard grains with a paste of a soft and elastic material. This consideration quite justifies the addition of powders or pigments to the bodies; we need not restrict ourselves to pure linseed oil, for instance.

5. The coating may be liable to develop cracks and breaks in the continuity of the surface. Such accidents may be ascribed to two chief causes.

a) The powdered material mixed with the body of the paint does not sufficiently adhere to the latter and separates from it under the inevitable contractions and dilatations. This will be

the case of certain inert materials: sulphate of barium, sand in mixtures with ochre, and others.

b) The body may be decomposed. This occurrence is almost always due to polymerisation or depolymerisation processes. Owing to the latter reaction certain oils give rise to the formation of simple hydrocarbons which act as solvents for the remaining substances. The colour then turns pitchy; the simple hydrocarbons are slowly volatilised, and hollow spaces and cracks make their appearance.

6. The powdered substance must be intimately united with the liquid mass of the body. Chemical combination between the components forms the most perfect bond, which will best resist any tendency to disintegration under the influence of dilatations and contractions; the lead oxides may be quoted as a noteworthy example.

7. Neither the body, nor the powdered substance should be liable to atmospheric corrosion by the oxygen and particularly by the furnace gases from large industrial works; zinc preparations, zinc oxide, zinc sulphide and the lithophones in particular leave much to be desired in this respect.

Of all the liquids which serve as paint body, linseed oil appears to us to be the best. It spreads in relatively thick films. Instead of diminishing in thickness by volatilisation, it gains in mass by absorption of oxygen, and it is scarcely liable to deperdition.

Judiciously applied it never turns pitchy, nor is it inclined to crack.

It keeps sufficiently elastic, moreover, for years, at any rate.

Linseed oil can be obtained in different grades: as crude linseed oil, old linseed oil, as linseed oil merely boiled in air, as standolie de Hollande, as thickened linseed oil boiled with litharge or with manganese peroxide.

The crude linseed oil, when well clarified, is relatively light in colour and readily taken up. It is, however, a little more fluid than the boiled oil and spreads in slightly thinner films. During its oxidation it loses from 6 to 8% of the decomposition products of glycerin; for this reason it forms blisters when applied in the hot, or especially as long as hot.

The old stored linseed oil is very clear, loses little by oxidation, dries pretty rapidly and is superior to the just described raw oil. But it rarely comes on the market.

Linseed oil, simply air-bottled (kettle-boiled) differs little from the two grades mentioned and need not further be dwelt upon.

The oil which is designated standolie de Hollande is a clear oil of considerable thickness; but it dries very badly and can only be used as an additive in the proportion of 20 or 30%.

Linseed oil, boiled with litharge or manganèse peroxide, is a comparatively thick fluid, which does not diminish in mass while drying, does not throw up blisters, and which requires only a very small quantity of artificial siccative; but it is of a very dark colour. We recommend this last mentioned grade of oil for all rust-preventing paints, when the shade of colour is not of importance, and when the quality of the oil can be controlled. The oil must be absolutely free from manganese resinate, because this product is subject to depolymerisation, to turn pitchy and to crack.

Pigments. We will now pass to the diverse powders or pigments which are mixed with the linseed oil. Experience shall be our guide. My own experiments have demonstrated, that lead white mixed with inert powders such as sulphate of barium, in the proportions of 25, 50, 75% of barium sulphate, possessed a rust-preventing capacity which was almost directly proportional to the percentage of lead white. In other words, in panels of iron, painted under the same conditions and examined at certain intervals, spots made their appearance whose intensity was approximately proportional to the percentage of the barium sulphate present in the paint.

Lead white paints, paints containing iron oxide (iron minium), minium (lead oxides), or graphite have resisted best. Zinc oxide is far inferior to these pigments; zinc sulphide and lithopone (mixtures of zinc sulphide and barium sulphate) are worthless.

Conclusion.

In my opinion we should, in the actual state of our knowledge, impose the following conditions concerning paints which are to protect iron structures from rust:

The paint should consist of iron minium[1]), prepared with boiled linseed oil[2]) under exclusion of essence of turpentine.

The determination of the amount of siccative to be used may be left to the superintendent in charge[3]).

So far as my own experience goes, equally good results are realised when graphite is substituted for the iron minium. The graphite must also be reduced to an impalpable powder and should contain at least $55^0/_0$ of carbon.

The quantity of powdered pigment which should be mixed with the linseed oil may be left to the judgment of the painters.

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[1]) The minium of iron shall be ground to an impalpable powder; a model of a pattern apparatus for this purpose will be produced. The fineness will, in any case, be sufficient when the powder stirred with water and applied to a glass plate in the state of a fluid paste, does not allow any grains to be felt when rubbed with the finger. The minium should contain at least $75^0/_0$ of ferric oxide and be free from sulphur.

[2]) The boiled linseed oil should be obtained from a clear pure oil, boiled with litharge or manganese peroxide, until its specific gravity attains at least the figure 0·939.

[3]) As regards the siccative, the superintendent should make a trial, three or four days before the commencement of the work, by painting a panel with the prescribed composition, but without using a siccative. The proportions will have to be adapted to the suitable period of drying. That period will depend upon the temperature, the necessity of keeping off the dust which may be troublesome at the time, the urgency of applying the second coating, and other features. It will be borne in mind that paints which contain the minimum amount of siccative are the best.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

VII3

METHOD FOR DETERMINING ELASTIC AND CRITICAL STRESSES IN MATERIALS BY MEANS OF THERMO-ELECTRIC MEASUREMENTS.

By **E. Rasch**, Groß-Lichterfelde.

Translated from the German by H. Borns, London.

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§ 1. Object.

The method, on which I have briefly to report, has been worked out in the course of the last few years in the Königliche Materialprüfungsamt at Groß-Lichterfelde near Berlin. On February 20, 1908, Professor A. Martens brought the subject before the Kgl. Preußische Akademie der Wissenschaften[1]) in a meeting of the Physico-Mathematical Class of the Academy.

In applying materials we should know the limits, p_x, beyond which the materials should not be stressed, lest the inelastic permanent deformations should assume values which would imperil the safety of the structure.

There is no general agreement as to the physical definition of these critical stresses which are commonly designated as elastic limit, limit of proportionality, or yield point. We might lay down as a matter of principle that specific maximum load p should be regarded as the elastic limit, at which the corresponding permanent changes in length β just exceeded the value zero. Within this limit the body in question would, when submitted to varying stresses of any kind, exclusively undergo purely elastic deformations, and would thermodynamically pass through perfectly reversible closed cycles.

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[1]) E. Rasch, Bestimmung der kritischen Spannungen in festen Körpern, Sitzungsberichte, 1908, X, p. 210—220.

The objection must be raised against this definition that the point at which β becomes $\geqq 0$ will be displaced with the perfection of the method applied.

Moreover, the irreversible deformations β increase continuously and in a regular manner in a large number of materials with increasing loads, and it is slowly and hesitatingly only, that the total extensions become apparent as deviations from Hookes straight line $p = \varepsilon E$. In all these cases a definite statement as to the position of the elastic limit cannot be made without a certain arbitrariness.

In view of the high commercial importance of the elastic limit some authorities prescribe for acceptance tests, in order to avoid this uncertainty, that a permanent extension of 0·2% — a figure chosen in a purely arbitrary way — should be regarded as characterising the so-called "practical limit of elasticity", the yield point, which should not be exceeded.

Measurements of elastic deformations are at present, in technical physics, mostly conducted with the aid of Martens[1]) mirror extensometer; elongations of $^1/_{100000}$ cm per scale unit can still be measured, and the manipulation of the apparatus must be granted to be convenient. All the same, the plotting of a complete elongation curve calls for a technically experienced observer.

The task was hence to find a method for the determination of the critical stress ($p_\varkappa$) which would so far as possible be exempt from arbitrary interpretation and which would, as regards simplicity and rapidity of the measurements, meet the requirements of technical practice.

The electric determination of the variations in temperature which accompany the deformation of a specimen under external stress has met these requirements.

§ 2. Thermodynamic Basis of the Method.

The thermal changes which the stretched specimen undergoes have been exposed by W. Thomson (Lord Kelvin) and Clausius on the ground of the general considerations of the mechanical theory of heat[2]), though only for purely elastic deformations.

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[1]) Compare A. Martens, Handbuch der Materialienkunde, 471.

[2]) Mechanische Wärmetheorie, Braunschweig, 1887, vol. I, p. 196.

Joule (1859)[1], Edlund (1865), Haga (1867), Wachsmuth and others have experimentally confirmed the strict validity of these thermodynamic deductions. Among other verifications, Edlund has determined the mechanical equivalent of heat from the temperature variations in elastically stretched rods, and Hirn[2]) from the thermal changes in lead cylinders under dynamic compression.

Thermodynamically, we may briefly argue in the following way when dealing with tensile tests:

When an elastically stretched rod of metal (length $L = 1$, cross-section $F = 1$) undergoes under a force p at the absolute temperature T a purely elastic elongation, the rod will cool by:

$$-\Delta T = \frac{T\alpha}{m\varkappa} \cdot \Delta p \text{ degrees},$$

where α is the thermal coefficient of expansion, $\varkappa$ is the specific heat of the material, expressed in mechanical terms, and m the density of the material.

The test rod will, until true equilibrium is established, take up a quantity of heat (ΔQ), which is withdrawn from its warmer surroundings.

Conversely, when the load is removed, the body will heat and will transmit heat to its surroundings by radiation and conduction.

We therefore have to deal with a reversible Carnot cycle. When the tension stress p is coutinuously increased, however, permanent deformations will become apparent in addition to the elastic extensions.

The component of the external work spent in internal friction (molecular rearrangement), will in any case result in a heating effect. It can be proved thermodynamically, and it will be understood on further consideration that, the equilibrium between the external and internal forces will be disturbed, when the work done in friction (i. e. heating) predominates over the work done in deformation (i. e. cooling).

This critical point in the tension test is therefore fixed by the observation that:

$$\frac{\Delta T}{\Delta \lambda} \geqq 0, \quad \text{and} \quad \frac{\Delta T}{\Delta P} \geqq 0.$$

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[1]) Phil. Trans., 1859.

[2]) Théorie mécanique de la Chaleur. Paris, 1876.

Starting from this point, the test rod will, with increasing force, continue to impart heat to its surroundings. If it be permitted to neglect, in the case of a rod of sufficient length, the influence of the parts where the rod is gripped, the heat which leaves the body in the unit of time (t) $-\frac{\Delta Q}{\Delta t}$ is nothing but the radiation Φ of the rod. According to the law of Stefan-Boltzmann-Planck, the radiation $\Phi = a\,(T^4 - T_0{}^4)$ is a universal function of the absolute temperature T of the radiating surface and of the temperature of the surroundings T_0.

We have further to bear in mind that the specific heat c of the specimen will essentially influence the temperature changes as well as the elongation curve. According to the generalisation of Dulong and Petit, the product: atomic weight M by specific heat c, has a constant value for all metals (in thermal terms $cM = 6{\cdot}38 =$ constant). It appears probable hence, that there is a thermodynamic equation of state connecting the strengths of all metals with their molecular structures and their thermal properties, and further that this general equation must be of a comparatively simple form.

§ 3. Experimental Method.

When we measure, by means of suitable apparatus, the temperature of a test rod while the test is proceeding, the critical stress $p_\varkappa$ (yeld point, elastic limit, limit of proportionality) will be recognised by the reversal in the temperature records. It is, of course, presumed that the temperature indication does not lag behind the stress indication. For practical purposes calorimetric measurements, such as have been published by H. Hort, while this search was proceeding, would hardly come into consideration therefore.

The temperature determination with the aid of thermo-couples has proved both simple and reliable. The junctions may be arranged in different ways with regard to the specimen, without noticeably influencing the reliability of the results. We have used thermo-couples of silver-constantan, copper-constantan, iron-constantan, consisting of wires, about 1 m in length and 0·5 mm in diameter, soldered with a soft solder or with silver.

It has resulted that it is by no means necessary to connect the soldered junction with the rod by means of metallic soldering. It will suffice to press the junction of the wires against the rod with the aid of a rubber strap or by similar means.

The cold junctions of the couples which were clamped to the wires leading over to the galvanometer, were as a rule placed in a common oil tank.

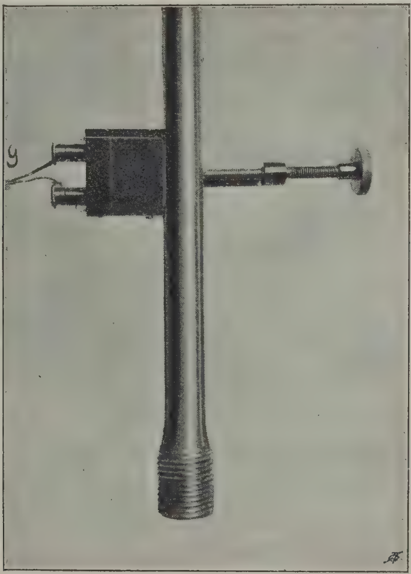

Fig. 1.

Galvanometers of small period and not of too large a resistance, having a sensitiveness of $1 \cdot 10^{-8}$ ampere, will suffice as temperature indicators. A small Edelmann chord galvanometer has proved well suited for the study of rapid deformations. The oscillating system of this galvanometer consits of a gold thread of a resistance of 87 ohms and of a diameter of 0·0085 mm which will be deflected parallel to the scale plane, under the electrodynamic influence of the thermo-current passing through it on the one hand, and of an electromagnetic field normal to the micrometer scale, on the other hand. Readings are taken with the aid of a microscope which is attached to the galvanometer and focussed on the gold thread.

For practical purposes it may be more convenient to make the observations with the aid of a mirror galvanometer, throwing its spot of light on a scale.

We have made use of an Edelmann torsional coil galvanometer, attached to the wall, whose frame resistance amounted to 4·7 ohms. Care must, of course, be taken to suspend it in such a way that no shaking need be feared.

It is also important to guard the test rod and the junctions against draughts during the experiment. When the thermo-couple wires are fixed, as indicated, it is hardly possible to avoid touching and thus locally heating them. The commencement of the real test should hence be delayed until the galvanometer has come to rest.

For these reasons a special thermo-pile, illustrated in fig. 1, has been provided for practical work.[1])

The thermo-pile consits of an ebonite box which is clamped with its front to the surface of the rod. This front is formed by a plate of soft rubber, fitted with a longitudinal slit in the centre. Within this slit the nine thermo-junctions are so arranged in series that they do not come in contact with the surface of the rod; otherwise the soldered junctions would be short-circuited by the rod. The cold junctions are connected with the binding screws at the back of the box (which is narrower there) to which the galvanometer leads are joined.

§ 4. Tests.

It will suffice on this occasion to indicate the general character of the many experiments with the aid of the curves, fig. 2.

These curves concern a brass rod which was in an annealed condition at the line a.

The stress recorder on the Pohlmeyer machine did not give any indication of stretching. The galvanometer curve (line a), however, marks the yield point as sharply defined minimum at $P = 3610$ kg ($\sigma = 1150$ kg/cm^2).

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[1]) The just mentioned experimental arrangements are due to the physico-mechanical institute of Professor Edelmann at Munich, to whom I am anxious to express my best thanks on this occasion.

The other curves (b, c, d, e, f) mark in the same way, by well-defined inflections, the yield points which had been raised by the previous loads.

In cast iron the reversal occured only at the moment of fracture.

It should be mentioned that the thermoelectric method has proved efficient, among other instances, in determining the stress distribution and the position of the layer of neutral stress in

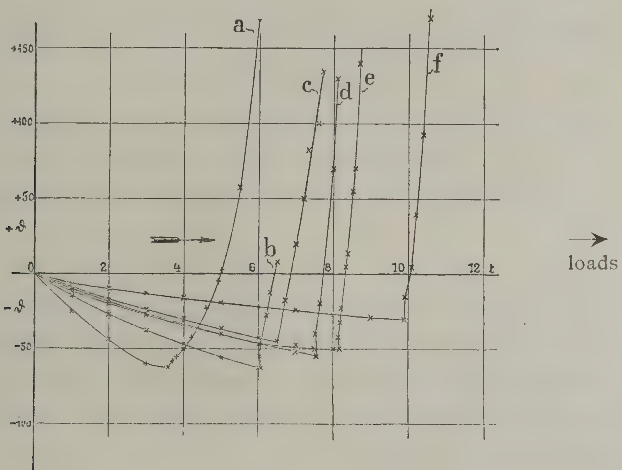

Fig. 2.

bending tests of girders; in this test the thermo-junctions were placed at different levels in the cross-section of the girder. The fibres stretched under load are recognised by a fall in temperature ($-\vartheta$), the compressed fibres by a rise in temperature ($+\vartheta$); the stress-strain distribution and the position of the layer of neutral stress ($\vartheta = \pm o$) are thus indicated. It is interesting to note from experiments with girders provided with broad flanges (height $h = 30$ cm) that with small spans the layer of neutral stress is displaced towards the tension side (up to $e = {}^1/_4\,h$), to an extraordinary degree.

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X9

ON UNIFORM METHODS OF TESTING PLASTER.

Report to problem 40, by **M. Gary**, of Groß-Lichterfelde, and **R. Feret**, of Boulogne-sur-mer.

Translated from the German by Dr. H. Borns, of London.

So far most of the mechanical tests to which different kinds of plaster of Paris habe been submitted, with a view of classifying them as to quality, have failed to yield concordant results. The deviations may be ascribed partly to disturbing influences of the methods applied, and partly to the want of uniformity in the samples.

When we are better acquainted with the physical and chemical properties of calcium sulphate, in its different states as anhydrides and hydrates, we may perhaps find more reliable and accurate means of distinction in the microscopical and chemical examination of plaster.

The Reporters are of the opinion that, at present at any rate, the examination of plaster and of the methods of testing it have not sufficiently advanced to justify their laying down rules for such tests.

They have hence resolved to propose that the problem be left to the consideration of a subsequent Congress.

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IX5

THE INFLUENCE OF SMALL-SECTIONED TRANSVERSE TIES ON THE STRENGTH OF CONCRETE. SYSTEM OF FREE TIES.

By **W. P. Nekrassow**, St. Petersburg.

(Translated from the French by A. R. Liddell, Charlottenburg.)

Abstract.*)

In 1907—1908 Engineer Nekrassow of St. Petersburg has made crushing tests on sample cubes of concrete reinforced by separate transverse ties of iron wire arranged in lattice form and placed in the mass, the latter being mixed with scraps of iron wire. The following are the results of the tests: When the iron wires of the lattice are from 4·00 to 3·00 mm or still less in diameter, the influence of the reinforcement in increasing the resistance of the concrete to crushing is in every case as great as that of hoops; the same is the case with the scraps of iron wire when they are 0·50 to 0·25 mm in diameter.

At the same time Engineer Nekrassow describes his system of "free ties" in the members of a structure, in accordance with which he makes use of two series of independent transverse connections, so as to attain the most rational disposition of the metal.

At the International Congress of Copenhagen the reporter proposes the following resolution:

The Congress is of opinion that the proposals for the increase of the strength of concrete by means of reinforcements of the second order are of great importance. Amongst other things it will be of interest to know the results of the practical application of the system of "free ties".

*) The original paper is published in the supplements to the Congress papers.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

V^TH CONGRESS, COPENHAGEN 1909.

X10

TESTING PUZZUOLANAS TO DETERMINE THEIR VALUE FOR MORTARS.

By the Chairman of Committee 11, **G. Herfeldt**, of Andernach o/Rh.

Translated from the German by A. R. Liddell, Charlottenburg.

The Committee appointed for the solution of the abore problem consisted of the following members:

Chairman: *Herfeldt, G.,* Traßgrubenbesitzer, Andernach.

Vice-Cairman: *Segré, C.,* ingénieur, directeur de l'Institut expérimental des chemins de fer de l'Etat, Rome.

Members: *Camerman, E.,* ingénieur-chimiste de l'administr. des chemins de fer de l'Etat Belge, Bruxelles.

Van Bogaert, C., ingénieur principal des chemins de fer de l'Etat Belge, Anvers.

Gary, M., Professor, Abteilungsvorsteher des kgl. Materialprüfungsamtes, Groß-Lichterfelde.

Michaëlis, W., Dr., Cement-Techniker, Berlin.

Wagner, P., Ingenieur, Köln a. Rh.

Mesnager, A., professeur à l'Ecole des ponts et chaussées, ingénieur en chef des ponts et chaussées, Paris.

Feret, R., chef du laboratoire des ponts et chaussées, Boulogne-sur-mer (Pas de Calais).

Kaptein, A. P. M., Abteilungsvorstand bei den niederländischen Staatseisenbahnen, Utrecht.

van der Kloes, J. A., Professor der technischen Hochschule, Haag.

Arlorio, A., Colonello nel R⁰ Genio Militare, Direttore della Academia Militare, Torino.

Canevazzi, S., professeur à l'Ecole royale d'application pour les ingénieurs, Bologna.

Cattaneo, U., ing., Capo Divisione delle ferrovie dello Stato presso l'Instituto sperimentale, Roma.

Ceradini, professeur de l'Ecole polytechnique, Rome.

Giambruni, ingénieur, génie civil, Naples.

Giorgis, G., Dr., professeur de chimie, Ecole royale d'application pour les ingénieurs, Rome.

Guidi, C., ingénieur, professeur, directeur du cabinet des constructions de l'Ecole polytechnique, Turin.

Rebuffat, O., Dr., professeur de chimie, Ecole royale des ingénieurs, Naples.

Greil, A., Baurat, Vorstand der städtischen Materialprüfungsstation, Wien.

Hillinger, H., Hofrat i. P., Wien.

Bogdanoff, N., ingénieur civil, adjoint du Labor. méc. de l'Institut Imp. des ing. des voies de comm., St. Pétersbourg.

Konossewitsch, F., ingénieur des voies de comm., Labor méc., St. Pétersbourg.

Lundteigen, A., chemist, Union City, Mich.

In recognition to the value of the Report presented by the Chairman of the Committee and of an annex by M. R. Feret, the IVth Congress in Brussels decided to refer the problem to the Committee for the carrying out of further experiments.

The Chairman accordingly sent round the following circular to the Members oft he Committee:

Andernach a/Rh., April 11th 1908.

Gentlemen

In view of the circumstance that, after the protracted winter, better weather has set in with the spring, I think the time has come to resume work on the investigation of the question referred to us.

I beg, therefore, to invite the members to take part in the further experiments, the details of which will be given further on, in order, if possible, to establish bases for agreement on points connected with the solution of our problem for the Congress to be held in Copenhagen in 1909. It will be remembered that,

in view of the fundamental differences of opinion of individual members of the Committee in regard to the establishment of proper methods of testing the puzzuolanas, it was decided at the last congress in Brussels to refer the question back to the Committee, who were then to make further experiments.

In my statements here following, I should like to make brief reference to the more important points in the results of our labours hitherto. It was, in particular, the question of the lime which occupied our attention, a part of the opinions taking the direction of applying it in the form of lime pulp or paste, while the remainder leant towards its use as a powder.

My present proposals are, that the use of lime pulp be standardised, because this gives a considerably higher degree of safety in connection with the main point, namely the slaking of the lime. It is of course left to the discretion of each member of the committee to carry out the tests with rich lime slaked to powder. Should several members prefer this, it will then be most clearly evident, which kind of lime gives the most regular results. In giving particulars of the results, the members are requested to state, in what manner and how long before use the lime was slaked to powder.

In regard to the way of slaking the lime, it will then be desirable to work out a set of special rules. The most important factor to be here taken into account is the choice of a lime which contains at least 96% of CaO. At the slaking only thoroughly burnt pieces of the greatest purity should be chosen. In this manner each country could lay down definite conditions for a so-called standard lime.

The storing of the lime paste, which is also a very important point in the lime question, would for instance take place in a pit specially set apart for it, and in this respect the Committee could very well adopt the rules decided upon by the German Association. These, as we know, provided that the slaking-water should stand for awhile above the lime, and that only the upper $^3/_4$ of the (lime-) milk should be let into the pit, so that the less easily slaked parts remained behind in the pan. The milk is then let into a masonwork pit built in two divisions, one of which is always kept filled and closed, while the standard lime from the

other goes to market in airtight receptacles of two different sizes to be determined later.

Then the degree of fineness of grinding of the puzzuolanas has, in the second line, been the subject of special observation, and experiments have already been made on it. Here I incline to the view, to which I have already given expression on page 31 of my committee report of **1906**, that a fineness of 30% — at most, however, of 20% — residue on the 900-mesh sieve should be required. A further fining, in particular of the Rheinish puzzuolanas (the trass) is useless, for the reason that residual particles of a more stoney kind only would thus be further refined, which have a purely mechanical effect on the mortar mixture, but not the chemical one which is of the most consequence for its technical examination.

As I have already mentioned in the passage of my earlier report above referred to, the composition of the sand as proposed by M. R. Feret is a very advantageous one and accords with the conditions of practice. This Feret composition depends, as we know, on the distribution in equal parts by weight of the three following sizes:

1. Grains which pass through a sieve with holes of 2 mm in diameter and remain on another one with holes of $1\frac{1}{2}$ mm in diameter.

2. Grains which pass through a sieve with holes of $1\frac{1}{2}$ mm in diameter and remain on another one with holes of 1 mm in diameter.

3. Grains which pass through a sieve with holes of 1 mm in diameter and remain on another one with holes of $\frac{1}{2}$ mm in diameter.

Finally attention may be called to the question still awaiting decision, as to whether it is advisable to divide the investigations into those in which the puzzuolanas are tested with reference to their technical value in mortar, and those which provide bases for research as regards their value in building construction practice. In regard to this I stand on exactly the same ground as M. R. Feret who terms the first group characteristic tests and the second one practical tests.

I have accordingly paid attention to the above-named leading ideas in the testing proposals which I have now formulated, and

I believe that, when the results or at least a part of them are forthcoming, we shall have advanced a step further towards final conclusions on the question submitted to us. I may observe further, that I would at once place the necessary amount of trass at the disposal of all the gentlemen who intend to take part in the investigations, whenever they express the wish for it, and I shall be pleased if those who decide to do so will let me have word to that effect within eight days.

The request for such consignment should not be delayed longer than this, since the date of assembly of the congress is approaching nearer and nearer.

Tests.

The tests are to include the following:

1. Setting tests (needle tests), on material of constituent parts apportioned by weight:

2 parts by weight of trass
to 1 part „ „ „ lime powder, and
3 parts „ „ „ trass
to 1 part „ „ „ lime powder.

2. Strength Tests. Admixture according to weight-relation of parts:

1 part by weight of trass,
$1^1/_2$ parts „ „ „ lime paste,
3 „ „ „ „ Feret sand.

Further, the mixture:

1 part by weight of trass,
2 parts „ „ „ lime paste,
6 „ „ „ „ Feret sand.

While in the needle tests (setting tests) the water necessary to produce the standard consistency is to be added, for the tensile and compression tests (strength tests) all the mixtures are first to be made in standard consistency and then also in completely plastic condition, as desired by M. Feret. For the needle tests I have proposed lime powder in view of the circumstance that only small quantities of mortar have here to be mixed and it is in consequence more difficult to produce these in a state of intimate combination with lime paste.

For the tensile and compression tests, however, I proposed lime paste obtained only from rich (white) lime, in particular in order to be able to observe the influence exercised by a pure lime. All the mixtures are then to be made — this applies also in the case of the needle tests — on the 900 mesh sieve with trass of a fineness of 30% and with such of only 20%.

The Members of the Committee, then, who wish to take part in the tests must prepare material of this degree of fineness by the granulometric admixture of the quantities required. The manner of production also must conform exactly with that of the standards hitherto in existence. In view of the great influence well known to be exercised by the initial temperature of the hardening water, particular care must be taken that it does not fall below a minimum of 15° C., while, for the rest, a water-temperature averaging 15—18° C. is to be observed during the whole time of immersion.

The whole of the test samples — this applies to the tensile test and compression-test samples — are then to be kept for one day in damp, that is to say in water-saturated air in a hermetically sealed zinc receptacle, and then immersed in water (fresh water).

In order to preserve the tensile test samples in as undamaged a condition as possible, the removal of these from the moulds would have to take place not less than six hours after their completion. The compression test samples, on their part, should not be removed from the moulds till after the lapse of 24 hours after their completion.

In connection with this latter point I have often had occasion to notice that a trass sample, by reason of its high degree of plasticity and especially also in view of the slow initial hardening of this mortar, was, on account of a small deformation of its figure, made to show disproportionately low strength values.

Testing Times.

After 15 days
" 1 months
" 3 "
" 6 "
" 12 "

The tests set forth in the foregoing will in my opinion be such as to show, to what extent lime in the form of pulp — when

a lime of good pure quality is in question — lends itself to the determination of the technical fitness of the puzzuolanas for the manufacture of mortar.

The different degrees of fineness of the trass meal will provide bases for consideration of the question, in how far such fineness is of importance in connection with the testing problem.

The employment of smaller and larger additions of sand will likewise afford a contribution to the question, whether in the uniform testing of the puzzuolanas only one (the richer) kind, or whether both kinds (the poor mixture as well) could suitably be allowed places in the testing method.

Jours faithfully

G. Herfeldt.

In answer to this circular the following answers were received from the Members of the Committee.

1. From Professor **van der Kloes**, of Delft, that want of time prevented his taking part in the experiments.

2. Dr. **Michaëlis** writes:

"Although I have, on account of my health, already severed "my connection with all Committees for the testing of materials, "I beg, notwithstanding, to make some observations in answer "to the last circular.

"In the first place I may call attention to the circumstance, "that the expression "lime-powder" must in every case be replaced "by "calcic hydrate powder"; for although it may be well enough "understood that in this case and connection $Ca(HO)_2$ is meant, "this is nevertheless erroneous; for lime powder alone is only CaO.

"The mixture one part by weight of calcic hydrate powder "to four parts of puzzuolana is in my opinion much too poor "in lime. The maximum ought to be 20 CaO to 80 puzzuolana, "that is to say 26 5 $Ca(HO)_2$ to 80 puzzuolana, but neither ab- "solutely dry nor carbonic-acid-free calcic hydrate powder should "ever be made use of; for nothing attracts carbonic acid more "rapidly than the loose, damp, calcic hydrate powder, even at its "manufacture and in its sifting and storing.

"Lime paste and lime pulp keep much better when covered "by a layer of water (like butter when covered by brine). You, as "agriculturist, will no doubt be doubly ready to agree with me in "this. Further a mixture of puzzuolana with lime-pulp will always

"be stronger, because it gives a mortar that is much more thoroughly "mixed, close-grained, and heavy. Instead of 20 calcic (hydrate) "powder to 80 puzzuolana, then, it should be 30 calcic hydrate "powder to 80 puzzuolana. About 26·5 $Ca(HO)_2$ will then be used "as an effective quantity of lime.

"We can, of course, make the experiments as we like; "uniformity is the main point; but we should certainly make them "with lime pulp, if the best results are to be attained. There "exists a completely reliable method of producing lime thoroughly "slaked to the finest pulp—my method. Suggest to M. René Feret, "then, that he use 75 calcic hydrate powder, 200 puzzuolana, and "750 mixed-grain sand."

After the Chairman had brought this letter to his notice M. **R. Feret** wrote:

"In receipt of the copy of Dr. W. Michaëlis' letter, which "you kindly forwarded to me, I will not revert to the question, "whether lime in pulp form or lime slaked in the form of powder "is to be preferred for the standard test of the puzzuolanas. All "possible arguments for and against the two methods, have, I "believe, already been adduced; every member of the committee "had them in full view, and has probably formed a clear and "decided opinion on them, which can be shaken only by convincing "experiments. The question will, moreover, not be finally solved "until it has been established by experiment, in which of the two "conditions the lime for the test can be obtained and continuously "kept with the exactly-determined percentage of pure $Ca(OH)_2$ "most easily.

"With reference to the mixing-proportions of calcic hydrate "and puzzuolana, I am not aware of the considerations on which "Dr. Michaëlis bases his opinion and the figures proposed.

"The mixing proportions proposed by me are based, not "upon theories, but upon experiments in which I established the "fact that this mixture in general yielded the strongest mortar. "Furthermore, I subsequently checked it, and it may be seen from "the Table D, given in my Brussels report, that the mixture of "1 part lime with 4 or even 5 parts of puzzuolana almost always "gave higher strength than those which contained only 3 parts of "the latter material; still less satisfactory must be the hardening "with the mixtures 80 : 30, 200 to 75, or 26,7 as Dr. Michaëlis

"now proposes. The figures given in the Chapter N of the same "report also show, that if we start with the mixing-proportion 1 : 4 : 15, "which I was led to propose, and increase the percentage of lime "at the expense of that of puzzuolana, which means a shifting of "the point N with reference to the side C S parallel to the side P C, "a diminution of the strength of the mortar almost always results."

Professor **Gary** writes:

"I am obliged by your circular concerning Committee No. 11 "of the International Association for Testing Materials, and in reply "beg to say that, while holding the institution of experiments as "proposed to be highly desirable, I am extremely sorry that I am "personally not in a position either to make the desired tests myself "or to have them made by others. The Königl. Materialprüfungsamt, "also, before which I have laid your proposal, is not in possession "of means for conducting tests of so extensive a nature. Perhaps "the Minister der öffentlichen Arbeiten in Preußen may be prepared "to place at disposal the means necessary for the carrying out of "the experiments; meanwhile a petition to this effect can be ex- "pected to elicit a favourable answer only if those interested in the "matter — in this instance the owners of the trass mines — also "contribute towards the expenses. Moreover, that such contributions "would be forthcoming, is also in this case uncertain.

"Under these conditions I shall be obliged if you will strike "my name off the list of the Members engaged on the International "Association's Problem 11."

6. Director **C. Segré,** of Rome, writes:

"In answer to your circular of last April addressed to the "Members of the Committee for the solution of Question 11, I beg "to inform you that the studies on the puzzuolanas in this Testing "Establishment of the Italian Railways (Instituto Sperimentale della "Ferrovie) have been carried on in accordance with the principles "which are put together in the accompanying memorial published "by the Italian Company for Materials of Construction. These principles are in general agreement with the views of M. Feret."

7. **A. Lundteigen** writes:

„I duly received your circular letter of April, and also letters "of May 12th, and May 13th, in reference to standard tests for trass "or puzzuolana, as used in mortar.

"There is not now enough time to make any tests; besides "my apparatus is all made according to English Standards, and "therefore not so easily comparable with the metric system.

"It would seem to me that your proposition, as outlined in "your letter and corrected according to Mr. Feret's suggestions, is "entirely satisfactory, and I have no doubt that we, in America, will "in due time adopt the same, or similar rules for the testing of Puzzuo-"lana, when used in mortar.

"As far as I know, this material is not at present used for "this purpose here, but I have reason to believe that it will be used very extensively in the future."

From the rest of the Members concerned with Question 11 no answers have been received.

Since none of the members have applied for trass and the reporter has received no notice to the effect that experiments have been made with other puzzuolanas in the manner proposed, we have unfortunately made no further progress with the solution of our question. It will probably also be a very difficult matter to establish uniform testing methods for the different puzzuolanas. In almost all countries in which puzzuolanas are found in considerable quantities special testing methods are already prescribed, which, although at times differing widely from one another, yet fulfil their purpose of determining the mortar-value of these materials for practical use in the countries in question.

The undersigned accordingly moves that the standards established in the various countries for the testing of the puzzuolanas, be collected and made known to the members of the International Association. A uniform method of testing, the results of which, obtained at different places and in different countries, can be compared one with another, can, to be sure, not be laid down, because the use of several kinds of lime and of sand respectively renders this impossible.

INTERNATIONAL ASSOCIATION FOR □
□□□□□ TESTING MATERIALS □□□□□

□ Vth CONGRESS, COPENHAGEN 1909. □

XI 2

□ ON THE CONDITION OF THE CEMENT □ BLOCKS IN SOME OF THE RUSSIAN PORTS □ IN THE BLACK AND CASPIAN SEAS. □

Abstract by **W. Czarnomski**, St. Petersburg.[1])

Translated from the French by A. R. Liddell, Charlottenburg.

The results of the expedition undertaken in 1904 by Engineer W. Czarnomski and Professor A. Baykoff to the ports of the Black and Caspian Seas with the object of visiting the piers and sea works and of studying the action of the sea water on cement mortar have been set forth in the inofficial report, made to the Brussels Congress in 1906, entitled „Sur la manière dont se comporte le ciment dans l'eau de mer."

Unfortunately, in consequence of an unexpected delay, the photographs of the different blocks and structures, taken during the expedition referred to, were not inserted in the report to the Brussels Congress.

In the report presented to the Copenhagen Congress in 1909 this deficiency is made good by the publication of the photographs together with a detailed description of the structures and of the blocks tested in the various Black Sea and Caspian Sea ports visited during the expedition of 1904.

Visits were paid to the piers and protective works at Petrovsk Poti, Odessa, Novorossisk, Theodosia, and Jalta, as well as to the dry docks and basins of Sebastopol and Baku. The 26 photographs of the various places, accompanied by a description of the structures

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[1]) The original report is published in the "Supplements to the Congress Documents."

and of the blocks tested, give a fairly complete idea of the condition of the concrete work, and lead us to the conclusion that the disintegration of cement blocks in sea water shows itself in two ways. In the first of these, the material, subjected for the most part to weak mechanical action, becomes covered with a more or less thick crust of carbonate of lime, and the disintegration occurs, not at the surface, but in the interior of the blocks; in the second case the blocks are exposed principally to the direct action of the waves, and are rubbed and worn down by the latter, so that they lose their corners and edges and finally assume surfaces of a more or less rounded form. The chemical reactions, which tend to destroy a block, consist, as shown by Mssrs. Chatelier, Michaelis, Feret, and others, of hydrate of lime near its outer surface, and of hydrate of magnesia and probably sulphoalluminate of lime in its interior.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

V^TH CONGRESS, COPENHAGEN 1909.

XI3

THE USE OF REINFORCED CONCRETE BESIDE THE SEA.

(Preliminary Communication.)

By Prof. **M. Möller**, Brunswick.

Translated from the German by A. R. Liddell, Charlottenburg.

On one of the sandbanks (Watts) of the North-Sea I had occasion 13 years ago to erect a small structure made of plates at a point not far from Husum, in order to test the use of reinforced concrete in the higher zone of the daily changing ebb and flow of the seawater-level. As shown by Fig. 1, the side view of the structure is of trapezium form; it has a ground area of 225×300 cm and a height of 80 cm. The lateral covering is of plates 7 cm in thickness with round iron reinforcements 8 mm in diameter. The plates were made by Messrs. Drenckhahn & Sudhop, of Brunswick, of a mixture of 1 part by volume of cement, $2^1/_2$ parts sand, and 2 parts crushed shingle.

The plates were erected in March, 1896, their age being about 40 days. On the evening of the 14th., as the sea ebbed, the foundations for the plates were laid by lamplight. A small ditch 25 cm in depth was dug in the muddy sand of the Watt and filled with freshly-mixed concrete of 1 part cement, 3 parts sand and 3 parts shingle. At night the site was under water. At 6 o'clock on the morning of the 15th. the work was continued. The erection of the plates began at half past seven and was completed in $2^1/_4$ hours. The joints were first coated at the side with cement-mortar of 1 part cement to $2^1/_2$ parts of sand. Finally pure cement was poured into the circular grove within the joint. At the base the plates were provisionally supported in a

framework of wooden laths 5 cm square in section, which rested on the pure concrete foundation and was made fast to the ground with stakes. Within the structure a floor of fresh concrete was laid. The space within was then filled with mud from the Watt, a clayey, easily moved sand, and on this the covering of fresh concrete 5 cm in thickness was laid. At 2 p. m. the sea water, now rising, came up to the finished structure. At its extreme level the water on this occasion rose only to a height of 35 cm above the lower edges of the plates, since it was held back by easterly winds. On the following afternoon the structure was completely under water, and during the night of the 17th. the high tide rose with a brisk WNW. wind to 1 m above the top of the covering plate.

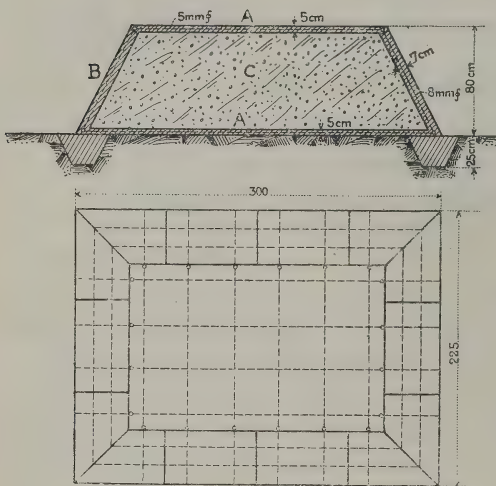

Fig. 1.

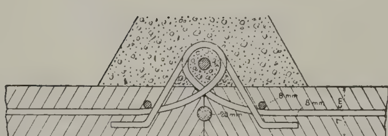

Fig. 2.

Fig. 2 shows details of the structure. The iron reinforcements projected from each plate at its joint in the form of eyes or loops in such a manner that the eyes from the adjacent plates stood one above another. A connecting round iron bolt 15 mm in diameter was passed through these from above. In way of the joints, again, wooden casings in the form of troughs were placed against the plates and filled with concrete from above, so that the eyes and their bolts were embedded in it. At the upper edges, also, of the plates the eyes projected in like manner to enable connection to be obtained with the reinforcements of the covering plates.

In the sequel it appeared that the concrete produced in situ hardened only for a time, and afterwards became soft when damp and friable when dry, and that whitish efflorescences were formed on its surface. The action of the waves, accordingly, made holes in the covering-plates of the little structure in less than 4 years after its erection. At first the holes were patched up again, but this process was afterwards given up. In order, however, to reduce the washing out of the fine-grained muddy sand filling, a layer of coarse sand was laid on the top of the cover.

I am acquainted with several other cases in which concrete or cement-mortar, that was brought in contact with sea water too soon after its production, has become soft and developed whitish efflorescences, as, for instance, the mortar of a lighthouse foundation which had been lowered in the form of a well, and, in another case, a ground-sill made of concrete rammed in the building-pit for a bank-protection covering, and again concrete coverings made on ground that was soaked with sea water during a previous flood. In three cases the official in charge of the work put the question in my presence to the contractor, whether he had put plaster of Paris in the cement, seeing that the material had become so white. The cause of this phenomenon, however, lay in the destructive action of sea water on freshly made concrete, of which I myself was first made aware by my experiments described above.

While the freshly-made concrete did not prove satisfactory in the structure, and the upper iron reinforcements, which on its destruction were laid bare, very soon rusted through and disappeared, the plates themselves, the concrete forming which was 40 days old before coming in contact with the sea water and had therefore already become hardened, behaved exceedingly well; and the iron reinforcements of the latter behaved equally well, so far as their condition could be ascertained. The surface of the concrete plates had only become somewhat rough. This little structure is to be surveyed in September of this year and then taken down. The plates, which have now been subjected to the actions of sea water and air alternately for 13 years, will be preserved, one of them in the laboratory of the Verein Deutscher Portlandzement-Fabrikanten at Karlshorst, near Berlin, another in the mechanical laboratory of the Technical College in Brunswick, and a third in the Cement Construction Works of Messrs. Holm & Molzen in Flensburg, which firm assisted in the building of the experimental structure.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

XII₁

WEATHERING RESISTANCE OF BUILDING STONES.

Report of the Chairman of the Committee, Prof. **A. Hanisch**, Vienna.

(Contributions by Professor Dr. J. Hirschwald, of Charlottenburg, Prof. Dr. H. Seipp, of Kattowitz, and M. E. Leduc, of Paris.)

Translated from the German by A. R. Liddell, Charlottenburg.

The Zurich Congress of 1895 propounded the following questions for study:

Question 7.

a) Appreciation of the connection existing between the chemical composition of the natural building stones and their resistance to weathering. Investigation into the influence of the smoke gases, especially of sulphurous acid.

b) Methods for the examination of the quality, and in particular of the resistance to weathering of roofing slates.

As a result of the welcome entrance into the Committee, since the Brussels Congress, of the following gentlemen:

Gary, M., Prof., Groß-Lichterfelde,
Hirschwald, J., Prof., Dr., Geheimrat, Charlottenburg, and
Leduc, H. E., Paris.

The constitution of the committee appointed for the study of this question is as follows:

Chairman: *Hanisch, A.,* k. k. Oberbaurat and Chief of the Versuchsanstalt für Bau- und Maschinenmaterial at the k. k. Technologisches Gewerbemuseum in Vienna.

Vice-Chairman: *Larivière, P.,* Engineer, Paris.

Members: *Dietrich, E.,* Professor at the Technische Hochschule, Berlin (Germany).

Gary, M., Professor and Head of Department in the Königl. Materialprüfungsamt, Groß-Lichterfelde, West.

Glinzer, E., Dr., ordentl. Lehrer at the Gewerbeschule und Baugewerkschule in Hamburg.

Hirschwald, J., Dr., Prof., Geheimer Regierungsrat, Chief of the Mineralogisch-geologisches Institut of the Königl. Technische Hochschule of Berlin.

Seipp, H., Dr., Professor and Director of the Königl. Baugewerkschule in Kattowitz.

Leduc, E., Chef de Section at the Laboratoire du Conservatoire des Arts et Metiers, Paris (France).

Vogt, H. L., Professor of the University of Christiania.

Kennedy, A. P. W., F. R. S., London (Great Britain).

Siemens, A., London.

Greil, A., Baurat, Manager of the Städt. Materialprüfungsstation, Vienna (Austria).

Kournakoff, N., Professor, Institut des ingénieurs des mines, St. Petersburg (Russia).

Lamine, N., Professor, attached to the Inst. des ing. des voies des comm., St. Petersburg.

Maluga J., Professor at the Académie des ing. milit., Sankt Petersburg.

Perrimonde, Engineer, St. Petersburg.

Wikander, A., Professor, Göteborg (Schweden).

Grubenmann, Dr., Prof. at the Eidg. Polytechnikum, Zürich (Switzerland).

Lunge, G., Dr., Professor at the Eidg. Polytechnikum, Zürich.

Wartha, V., Dr., Professor at the Königl. Polytechnikum, Budapesth (Hungary).

Kemp J. F., Geologist, Professor at the University of New-York (United States of N. America).

Merriman, M., Consulting Engineer, 45 Broadway, New-York.

To the report laid before the Brussels Congress in regard to the progress of the work of Committee, the following addition must now be made:

The Members of Committee No. 7 some time ago expressed the wish, that the publication of the work of Herr Regierungsrat Professor Dr. J. Hirschwald should first be awaited. The important work by this author, entitled "Die Prüfung natürlicher Bausteine auf ihre Wetterbeständigkeit"*) (The Testing of Natural Building Stones in regard to their Resistance to Weathering), recently issued, which was written at the instance of the Prussian Ministerium für öffentliche Arbeiten, would now be in every sense excellently adapted to serve as a basis for the discussion of the newly established standards.

Since, however, the Deutscher Verband für die Materialprüfungen der Technik (German Association for Testing Materials), following up a suggestion made by Herr Landes-Geologe Dr. Leppla, has appointed a special committee for the solution of the same question, which consists of professional men of note, and which has begun its work with the support of the Jubiläumsstiftung der Deutschen Industrie, it seemed fitting, to await the results of the labours of this association, so that these also might be made to serve as bases for the discussions of the Committee.

Although, then, it was not possible at this stage to approach the Congress with a piece of Committee work, let alone with definite proposals, the Chairman wishes at least to place on record a series of suggestions and questions which have issued from the circle of the Committee Members and will have to be taken into consideration in connection with the study of the resistance of stones to weathering.

Thus Herr Geheimrat Prof. Dr. J. Hirschwald, in his letter of January 2nd., 1909, after pointing out that the real questions entrusted to the committee had received exhaustive treatment in his work above named and observing that he would leave to the Committee to decide, in how far the problem had thereby met with its solution, writes:

"I beg to propose the following as new questions, the "discussion of which by the International Association would be "urgently desirable:

„1. The examination of as large a number as possible of "stones of old buildings by the method made use of by the

*) Wilhelm Ernst & Sohn, Berlin, 1908.

"Committee of the Prussian Ministerium der öffentlichen Arbeiten, "in order to determine whether the estimates of the properties of "stones thereby formed also hold good for stones which show a "considerable degree of variation from the composition of the "materials hitherto investigated.

"2. The drafting on the simplest possible lines and in "accordance with the results of work hitherto carried out, of an "investigation schedule adapted for use in the material-testing "establishments.

"3. The framing of rules for the choice of the test materials "to be handed in to the testing establishments for examination "and for the preparation of the sectional drawing or description "of the section of the quarry in question."

Geheimrat Hirschwald was himself so good as to prepare a testing schedule such as that mentioned under No. 2. This has appeared in the form of a supplementary pamphlet to the Congress Publications, but a perspicuous abstract is attached to this report as an appendix. This testing schedule, which combines all the testing methods in accordance with the present state of science, is to be welcomed in the warmest manner possible, and is herewith submitted to the judicial consideration of the Members of the Committee and of the Association.

A matter of special importance would seem to be a thorough discussion by the Members of the Committee of the curtailed tests of resistance to weathering (dissolving and disintegrating tests) such as those laid before the International Association by the Member of Committee Director Professor Dr. H. Seipp, and for the improvement of which he submitted proposals to the Brussels Congress.

Not less desirable would seem to be the taking up of a position by the Committee in regard to the institution of tensile strength experiments in the testing of building stones for resistance to weathering, and the answering of the question whether after a frost the stones should be submitted to the strength tests in the dry, the wet, or the frozen condition.

In relation to this question a valuable study "Zur Theorie der Frostwirkung auf natürliche Bausteine" (On the theory of the action of frost on natural building stones), by Prof. Dr. H. Seipp has been received by the Chairman, and is likewise attached in abstract to the report of the Committee, while the

comprehensive study itself has appeared in the Supplementary Pamphlets. Prof. Seipp therein repeats his demand that before and after the frost tests the compressive strength experiments should in future be replaced by the tensile strength and shearing strength experiments, and calls attention to the various influences on which the nature and degree of the frost action depend, such as size of pore, form of pore, distribution of the pores, and capacity of the stone for absorption of water and softening.

A valuable suggestion is contained in the contribution made to the proceedings of the Committee by M. E. Leduc, Head of Department at the Laboratorium des Arts et Metiers of Paris, under the title "On the determination of the Resistance of Stones to Frost", which is also attached, in full, to the report as an appendix.

M. E. Leduc here submits the frost-resistance tests to critical examination and proposes a new accelerated frost-resistance method which he recommends to the Congress for re-investigation by scientists in different countries. The method recommended by him, which is fully described in his report, is as follows: The test samples (cubes of 70 mm length of side) of natural stone and fire-brick, are dried at a temperature of 100° C. till a constant weight is attained. (It would be advisable to put conglomerate stones under a bell with sulphuric acid or to dry them at a temperature of 40 to 50°. The success of the latter operation however, is doubtful.) The test samples are then immersed in water to a height of 20 mm. Following the level as it rises by the capillary action, water is added every half hour. When completely saturated, they are covered with water and weighed. Should the saturation not be visible, or should it be only slowly attainable through the surfaces of the cubes, these latter are entirely immersed in water for a period of 8 hours, reckoned from the beginning of the experiment. After an immersion of 24 hours, reckoned from the beginning of the experiment, the cubes are immersed for 4 hours in a solution of chloride of calcium of the density of 1·30 at a temperature of − 15, and four hours later in water of + 15° C.

The three works referred to, for which the Chairman here expresses his warmest thanks, were received by him at the eleventh hour, so that it was not possible for the Committee to devote their attention to them; they are to form the bases of further operations.

Finally the Chairman wishes here to recall the questions and suggestions, which Professor E. Dietrich, of Berlin, some time ago submitted to the Committee, and which are in part reproduced in the suggestions received from other quarters. These run as follows:

1. Is it, as stated with reference to homogeneous masses in a publication by Martens (Berlin), a matter of indifference also for investigations on stones, how large the test samples are. I cannot bring myself to this conclusion.

2. The quarry-owners send samples from their best beds, but they make use of the inferior ones as well. Of what use, then, are the test certificates? Should not, when a number of samples are submitted, a certificate be given by some local authority stating, whether the quarry shows a like quality of material through-out, or whether the samples are taken from the beds that are being worked?

3. Is is not necessary, in the production of samples from sedimentary rock, to pay attention also to the stratification, and to state whether the compression or tensile test, as the case may be, will be made in a direction parallel with the stratification, or at right angles to it.

4. Is the parallel guidance by the two screws of the Tetmajer machine so reliable that an upper joint plate, which is apparently wanting, can be done without? Even though the screws may, in the beginning, be exactly alike, they may wear unequally after years of work.

5. In the case of frost tests the magnifying glass should always be made use of, in order that alterations on the surface of the materials may be more easily recognised. Shall this not be universally prescribed, and also the microscopical examination of slices as advocated by Hirschwald?

The Chairman believes that he can express the hope, that by the study of this knot of questions and by the payment of the greatest possible attention to the excellent works and proposals of Geheimrat Prof. Dr. Hirschwald, as also in view of the results to be expected from the Deutscher Verband für die Materialprüfungen der Technik, it will be possible to work out definite proposals for the next Congress and thus to arrive at a good solution of this difficult question also. He accordingly moves that the Congress entrust the Committee with the further conduct of the work, in which attention will then be given to all the suggestions referred to in the foregoing.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

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XII$_2$

SCHEMES*) FOR TESTING NATURAL BUILDING STONES AS TO THEIR WEATHERPROOF QUALITIES.

By Professor Dr. **J. Hirschwald**, Berlin.

Appendix to the report of Committee 7.

Translated from the German by A. R. Liddell, Charlottenburg.

Tests to be applied	Sandstone	Graywache	Limestone	Roofing Slates	Granitic Stones and Crystalline Slates	Porphyry	Basalt
1. Microscopic Stone-Analysis[1]):							
a) Nature of grain-formation	1a	1a	1a	—	—	—	—
b) Binding-number and measure of binding (Page 259)	1b	1b	—	—	—	—	—
c) Mineralogical nature of the contact, pore, or basal-cement	1c	1c	—	—	—	—	—
d) Type of stratification (Page 256, Plates IV a and IV b)	1d	1d	1d	—	—	—	—
e) Percentages of granular constituents and cement (Page 141) . . .	1e	1e	—	—	—	—	—
f) Mean diameter of the granular constituents and number of them per sq. centimeter (Page 120) . . .	1f	1f	1f	—	1f	—	—
g) Special conditions of intergrowing (Contact surfaces, continuity, Page 446)	—	—	1g	—	—	—	—
h) Type of structure (Pages 442 to 446, 595, and 639)	—	—	1h	—	1h	1h	1h
i) Differing intercalation (Page 447) .	—	—	1i	—	—	—	—

1) The page numbers given are those of the work: "Hirschwald, Die Prüfung der natürlichen Bausteine auf ihre Wetterbeständigkeit". (Hirschwald: The Testing of the Natural Building-Stones as to their Weatherproof Qualities). W. Ernst & Sohn, Berlin 1908.

*) A detailed form has been published as a "Supplement to Congress reports".

Tests to be applied	Sandstone	Graywache	Limestone	Roofing Slates	Granitic Stones and Crystalline Slates	Porphyry	Basalt
k) Kind of porosity (Page 447) . .	—	–	1k	—	—	—	—
l) Micro-Structure of the mica layers (Pages 537 and 540)	—	—	—	1l	—	—	—
m) Morphological development of the mica layers (Page 537)	—	—	—	1m	—	—	—
n) Thickness of the mica layers (Page 540)	—	—	—	1n	—	—	—
o) Number of these to 1 mm of section	—	—	—	1o	—	—	—
p) Detrimental accessory constituents	1p	1p	1p	1p	1p	1p	1p
q) Degree of weathering of the feldspat or of the other constituents (Page 598)	1q	1q	—	—	1q	1q	1q
r) Structure (From "compact" to "loose")	—	—	1r	—	1r	1r	1r
s) Degree of silicification	—	ev. 1s	ev 1s	1s	—	1s	—
t) Percentage of so-called Glass-Basis (Page 642)	—	—	—	—	—	1t	1t
2. Determination of Porosity and of Capacity for Water-Absorption:							
a) Absolute porosity (Page 149) . .	2a	2a	2a	2a	2a	2a	2a
b) Relative porosity (Pages 152 and 45) (water-absorption at different pressures)	2b	2b	2b	2b	2b	2b	2b
c) Determination of the saturation-coefficient S (Theoretical Frost-Test, Page 152)	2c	2c	2c	2c	2c	2c	2c
d) Determination of the Distribution-coefficient V (Page 157)	2d	2d	2d	2d	ev. 2d	—	—
e) Water Absorption from the cleavage surface (Page 547)	—	—	—	2e	—	—	—
3. Colouring Test (Pages 165—169) .	3	3	3	—	3	3	3
4. Determination of the Strength of the Grain-Adhesion (Pages 266 and 326)	4	4	4	—	ev. 4	ev. 4	ev. 4

Tests to be applied	Sandstone	Graywache	Limestone	Roofing Slates	Granitic Stones and Crystalline Slates	Porphyry	Basalt
5. Determination of the Capability of being softened in Water:							
a) by means of tensile tests in a dry state and after continued immersion in water (Page 266)	5a	5a	5a	—	ev. 5a	ev. 5a	ev. 5a
b) by tests of hardness under the foregoing conditions (Page 196) .	—	—	ev. 5b	5b	—	—	—
c) by sediment-analysis (Page 200) .	ev. 5c	—	—	—	—	—	—
6. Tests by Heating (Pages 590 and 785)	—	—	—	6	—	—	6
7. Experimental Frost Tests with varying Degree of Water-Saturation (Page 273)	7	7	7	7	ev. 7	ev. 7	ev. 7
8. Chemical Tests for Separate Constituents (FeS_2; Carbon and its Combinations; CaO, MgO, FeO, Fe_2O_3, CO_2, Al_2O_3) according to the kind of stone	8	8	8	8	8	8	8
9. Determination of Quality of the Stone under Investigation according to the particular valuation-scheme	9	9	9	9	9	9	9

Comparison of the Testing Method hitherto in Use with that Now Proposed.

Method of Testing hitherto employed	New Method of Testing
1. Determination of Porosity.	Ad 1. Supplementary Process consisting in the determination of the Water-Absorption in a vacuum and under a high degree of pressure, or by the Determination of the Water-Absorption from the cleavage-surface and of the section. Calculation of the saturation-coefficient S and of the distribution-coefficient V.
2. Compression Tests on the Stone in Dry Condition and after Continuous Immersion in Water.	Ad 2. Supplementary or alternative process, consisting in the making of strength tests in which the test-results are referred to the sum of the surfaces of adhesion, for the purpose of determinig the strength of grain-adhesion.
3. Experimental Frost Tests.	Ad 3. Eventual supplementary tests with different degrees of water saturation. In addition: 4. Microscopic Analysis of the Stone. 5. Ev. Levigation Analysis and Colouring test. 6. Chemical Examination for individual constituents ($Fe S_2$, [Ca, Mg, Fe]CO_3, Fe_2O_3, Percentage of Clay, Carbon-Compounds; Behaviour of the "Glass-Basis" [if present] in Volcanic Stone, under the action of acids).

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XII 3

ON THE THEORY OF THE ACTION OF FROST ON NATURAL BUILDING STONES.

By Prof. Dr. **H. Seipp**, Kattowitz, Upper-Silesia.

(Abstract from the Original Report.)[1]

Appendix to the Report of Committee No. 7.

Translated from the German by A. R. Liddell, Charlottenburg.

Prof. Dr. Seipp reiterates the plea formerly made by him that the compression test be in future replaced by tensile and shearing tests made before and after the frost tests, and calls attention to the various influences which determine the manner and degree of the action of the frost, such as size of pore, form of pore, distribution of the pores, faculty for the absorption of water, and softening capability of the stone.

It is an indispensable requirement for the setting up of frost action, that the formation and growth of ice-germs are unable to proceed unhindered. In accordance with this, stones are frost-proof, 1. when the cavities communicate with each other by means of equally wide or only slightly varying outward-leading connecting passages, that are either straight or of a regular flattened form, 2. when the size of the pores is so small throughout, that the formation of ice is impossible, 3. when the width of the pores is exceptionally large, so that the entrance of water in sufficient quantity to cause ice-pressure appears out of the question, and 4. when great strength possessed by the material itself offers a certain guarantee against the action of the ice pressure.

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1) The original report appeared in the form of a supplementary pamphlet to the congress publications.

Of a still more manifold kind are the possibilities of danger from frost. Prof. Dr. Seipp shows the influence exercised by the relative positions and the distances apart of the cavities in the stone on the strains set up (compression, tensile, bending and shearing strains), and by the help of assumed figures illustrates the characteristic processes of, and the forms assumed by possible frost damages, such as abrasion of the surface, the phenomenon of the destruction of edges and corners, the formation of cracks, cleavages, and cavities, the exfoliation etc., etc., by the simultaneous appearance of which the most varied pictures of stone destruction are produced.

In the next-following section Prof. Dr. Seipp reports on the influence exercised on the ice-pressure by the degree of fulness of the pores and by the contraction of the stone. Since the coefficient of space-extension of the building stones is at least $3^1/_3$ times as small as that of the ice ($\alpha_E = 15 \times 10^{-5}$), as soon as an ice formation has appeared, the wall pressure of the pores will, on further cooling, somewhat abate. True, as Professor Dr. Seipp shows by means of a calculation, the abatement can only be of insignificant amount in comparison with the original degree of the ice-pressure.

If we assume that at the ordinary temperature ($+15^0$ C.) of the space in a stone-pore V a part V' of the latter be filled with water, the requirement for frost-proofness may be taken to be $v' \leqq 0{\cdot}91058 \times v$ — that for danger of frost $v' > 0{\cdot}91058 \times v$.

The degree of fulness of the pores, the part borne by which is characterised by the foregoing formulae, can be experimentally determined by the proportion

$$\frac{Pw}{Pv} = \frac{\text{Water Absorption Capacity}}{\text{Porosity}}.$$

Prof. Dr. Seipp shows how these two last mentioned quantities may be determined, and places them in relation to the influence of the softening undergone by the stone while being damped through. From the tensile, shearing, bending, and compression strengths (β') in the original dry state, the tensile, shearing, bending, and compression strengths (β'') in the softened condition, and finally the tensile, shearing, bending, and compression strengths (β''') under the influence of frost, the author

forms the coefficient of softening $\left(\frac{\beta''}{\beta'}\right)$ and that of weakening by frost $\left(\frac{\beta'''}{\beta''}\right)$, as also the frost-proof coefficient in case of softening $\left(\frac{\beta'''}{\beta'}\right)$, as measures of the resistance of the stones to the action of frost.

Prof. Dr. Seipp advocates that the determinations of strength be made after previous thawing (freezing and thawing being made to alternate 25 times), since damages that are probably not discernible till after thawing has taken place, are produced before the frost period, even though damage may possibly be in some cases produced, during the rising and falling of the temperature, by means of the high coefficient of expansion of ice under heat.

Finally Prof. Dr. Seipp discusses the question of the strength values for the poreless material, which might be termed the "real strengths". The strength tests now in use only give values for the strengths of the material with its cavities, which might be termed the "apparent strengths".

The determination of this apparent strength is entirely correct only in reference to the tensile strength of the stones under the action of frost. Almost the same may be said of the determination of the shearing-strength. On the other hand a discrepancy between reality and experiment shows itself where bending strengths come in question. In drawing attention to this circumstance, Dr. Seipp has lately given the first impulse to the resort to tensile and shearing experiments in connection with frost tests, and has at the same time forshadowed a series of new investigations of his own for the determination of the limiting values of the stresses really set up in the materials by frost action, and the improvement of his apparatus for the "accelerated agent test".

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XII4

THE DETERMINATION OF THE GELIVITY OF STONES.

Appendix to the Report of Commission 7, by **E. Leduc**, Paris.

Translated from the French by H. Borns, London.

If there is a test of incontestable utility for the value of building stones, it is certainly the determination of their capacity to resist the action of frost. Yet there are few tests so difficult to carry out, changing so much from laboratory to laboratory, and so much subject to different appreciations.[1])

As J. Marvà y Mayer points out in the communication on the estimation of gelivity which we have already quoted, there is no agreement as to the manner of drying the stone, nor as to the imbibition, nor even, we must add, as to the congelation, or the method of procedure in effecting the thawing.

We have made an attempt to work out an outline of suitable methods for such tests and we have for this purpose submitted a fairly large number of stones (31) recognised in practice as being much, little or not liable to suffer from frost, to different tests, in which we varied the manner of immersing and of freezing.

All these tests[2]) — except a few made on fragments with sharp projecting edges — have been carried out with cubes

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1) Not to render this report too long, we have refrained from describing the different modes of operation, which the reader will find without much trouble in the reports of the Conferences held at Berlin, Dresden, Munich, in the detailed memoir submitted by J. Marvà y Mayer to the Paris Congress of 1900, and in the report presented by Gautier to the Commission on Methods of Testing instituted by the Minister of Public Works.

2) It is owing to the kindness of Mr. Civet-Pommier, that we have been enabled to conduct this investigation; he has been good enough to place the specimens at our disposal, and we can not thank him too much.

carrefully cutwith neat edges having approximately a side length of 70 mm, taken from blocks of 400 by 400 mm.

Desiccation.

As the complete desiccation at 30 or 40^0 may take days and even weeks, we have chosen a temperature of 100^0, which ensures a rapid desiccation without any trace of disintegration.

Density. Specific Gravity. Porosity.

We have determined the density, specific gravity and the absolute porosity of the specimens.

The specific gravity has been ascertained by means of the Le Chatelier-Candlot voluminometer the powdered material being passed through a sieve having 900 meshes per cm^2.

In order to determine the absolute porosity, that is to say, the difference between the specific gravity and the apparent density, we have taken as density the mean of three results.

As the specific gravity of stones varies little, whilst their apparent density varies notably, it follows that the absolute porosity is all the greater, the smaller the apparent density.

Saturation.

We have applied two methods to ensure saturation: saturation by capillarity followed by immersion, and saturation in vacuo.

Saturation by Capillarity and Immersion. In this procedure the cubes were placed in receptacles and immersed to a height of 20 mm. Every half-hour water was added to the receptacle until its water level reached up to the height which the capillary ascension had attained; this height is easily recognised. The process was continued until the upper surface of the cube was completely imbibed. The cube was then entirely covered with water, and, half an hour later, wiped and weighed. The difference in the weights of the wet and the dry cube gave the amount of water absorbed by capillarity.

These imbibition tests prove that two cubes, cut from the same block of stone, may differ sensibly, according to the method employed and to the nature of the stone.

Moreover, the absorption is not complete even after four weeks of immersion under water, since of all the specimens tried

only Nr. 767, 769, 781, 782, 784 and 788 show an increase of less than 0·01 per cent at the end of four weeks of immersion.

Absorption in a Partial Vacuum.

For the saturation tests under the influence of a vacuum, the specimens were placed in a small autoclave, joined toa water pump. A depression of 60 mm of mercury was maintained for 30 minutes. Water was then admitted very slowly, and the vacuum was maintained for an hour.

On glancing through the columns of the tables the reader will at once notice that the amount of absorbed water determined immediately after these tests was very sensibly higher than the amount taken up by complete immersion, even after 4 weeks of submersion. If the specimens Nr. 771, 773, 778, 779, 782, have yielded smaller values, these differences must be ascribed to the nature of the stone, i. e., to its want of homogeneity.

We may hence conclude, without risk of making a mistake, that the proportions of water absorbed under the influence of a partial vacuum is sensibly higher than the amount absorbed during an immersion under water prolonged for four weeks.

The vacuum test may be regarded as yielding the maximum amount of absorbable water; for when the specimens of test series 6 were left immersed for 24 hours and for a week, an insignificant increase only was noticeable.

Relation between Density and Amount of Water absorbed.

The tests bring out, what was to be foreseen, that the stone will absorb all the more water, the less dense it is, or the greater the amount of empty spaces enclosed — the specific gravity being understood to remain the same (Table A).

Congelation.

The cubes[1]) ready for the freezing tests were placed within a cell of galvanised iron (an exception was made in test series 7, in which the specimens were directly plunged into the brine of

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[1]) Some experiments were made with fragments of smaller volume than the others; the edges were neat, however, and the angles right angles, as in the latter cases.

calcium chloride). The cell was lowered into a solution of calcium chloride kept at — 15 or — 18^0 C. by means of a carbon dioxide refrigerator.

Eight different methods were applied as described below. In all these processes the time is reckoned from the beginning of the imbibition.

1. The cubes were dipped into the water to a depth of 20 mm; water was then added every half-hour until the water level reached up to the height attained by the capillary rise. The cubes having completely been imbibed remained covered with water, were weighed, put back into the water, weighed after 24 hours of immersion, and then placed in the cell of the freezing apparatus.

2. As in 1, but with an immersion of 48 hours instead of the 24 hours of 1.

3. As in 1, but with an immersion of 1 week instead of 24 hours.

4. As in 1, but with an immersion of 4 weeks.

5. After having been saturated with water in a vacuum, the cubes were at once weighed and then placed in the cell of the freezing apparatus.

6. After having been saturated with water in a vacuum, the cubes were at once weighed, then immersed for 24 hours, and weighed again. They were afterwards immersed once more for a week, weighed a third time, and now placed in the cell of the freezing apparatus.

7. After having been saturated with water in a vacuum, the cubes were weighed and then at once plunged into the calcium chlorids brine of the freezing apparatus.

The thawing was effected in all these experiments, by placing the cubes, when taken out of the cells of the freezing apparatus, for four hours in distilled water of + 15^0 C. The cubes were then taken out again and stored in a hermetically closed vessel of glass, to be put back again into the cells of the apparatus the following day; before putting them back again into the cells, however, the cubes were once more immerged for 5 minutes, in order to compensate for the loss of the water which had evaporated during the various manipulations.

On examining the results obtained we see at once that the test 7 is extremely severe. Only one single stone No. 773, has

been able to stand this treatment. All the stones (except specimens No. 766 and 782) failed at the first thaw.

The saturation process in the vacuum, followed by an immersion of one week, likewise eliminates almost the whole number of stones.

It is to be noticed, however, that No. 784, although a very porous stone of small density, which absorbed a large amount of water (14·85 per cent), has stood this test.

Saturation in a vacuum, not followed by immersion, is a less severe, bot more rapid test than the preceding. This test shows, how a small excess of absorbed water suffices to bring about the disintegration of a stone. For in test 6 the stones have absorbed very little more water than in test 5.

The other tests are fairly equivalent, so far as we can judge from experiments with materials which are so little homogeneous.

It should be pointed out that, whatever the mode of operation, the result does not correspond to the amount of absorbed water. Thus, to give an example, one stone (No. 785, test No. 4) has been able to absorb 19·12 per cent of water without any danger, while other stones have been disintegrated, although they had only taken up a very slight amount of water. The statement of this fact is indeed logical; a very porous stone may prove stronger in a tensile strength test than a far less porous stone.

Finally, certain stones which in practical use are classed as not subject to damage from frost (767, 775, 776, 778, 780, 789, 794, 795) have not stood any of these tests, while others, classed as liable to suffer from frost, have resisted some of the tests to which they were submitted.

These tests (columns 1 to 7 in Table B) are not in accord with the experience gained in practice.[1]) This will easily be recognised when we compare the results condensed in the columns 1 to 7 with the observations marked in column 10 of Table B. We have therefore thought that, by modifying the process suggested

[1]) Information as to the practical value of the stones which we examined has been given us by the Chambre Syndicale des Entrepreneurs de Maçonnerie du Departement de la Seine, which has made an extensive enquiry in order to supply us with the practical detail. We are under the greatest obligatoin to the Chambre and in particular to its president, Mr. Villemin.

by Marvà y Mayer, in the manner indicated below, we might arrive at practical results.

The cubes (column 8 of Table B) have undergone gradual immersion for 24 hours; they have then been plunged directly into the brine for 4 hours and afterwards been thawed for four hours in water of $+15^0$ C. Every operation has been performed once only. Column 9 reproduces the data of cubes treated in the same way as those dealt with in column 8, except that the immersion lasted 48 instead of 24 hours. The results obtained by the two methods differ so little that we will only discuss the data of column 8, 24 hours' immersion.

When we compare the results of this test (8) and the practical experience (10), we notice that practical experience and test are in reasonable agreement.

This method of operation is extremely rapid, since the whole procedure occupies exactly two days.

It will moreover be understood that the tests as usually conducted are faulty as to the method itself. For the results will differ with circumstances to which attention has not been drawn; the specimen may touch the metallic wall of the freezing cell or be more or less close to it, and the volume of air left in the cell will vary.

Proposition.

On the strength of the research which we have undertaken we beg to propose that the Congress nominate some experimenters from different countries for the purpose of investigating the mode of operation indicated below in experimenting on different materials.

The specimens (cubes of 70 mm side) shall be dried at 100^0, until their weight be constant. This is to be done with natural products and with baked specimens (agglomerates will best be placed under a bell containing sulphuric acid, or be dried at 40 or 50^0 C., although this method of drying [between 40 and 50^0 C.] is of doubtful reliability). The specimens shall then be dipped into water to a depth of 20 mm. Water is to be added every half-hour, until the level of the water comes up to the height reached by the capillary rise. When completely imbibed, the cubes shall be covered with water and weighed. In cases where imbibition should not be discernible, or when it should attain the top of the tube

very slowly, the specimens shall be covered with water after 8 hours of imbibition, counting from the commencement of the operation.

After 24 hours of immersion, counted from the commencement of the operation, the cubes shall be suspended for 4 hours in a solution of calcium chloride of density 1·300, maintained at — 15^0 C. After this time the cubes shall be withdrawn and plunged for 4 hours into water kept at + 15^0 C.

This interval having passed, the cubes shall be withdrawn and examined as to their condition.

Summary

Number	Density (means of 3 cubes)	Specifice gravity	absolute Porosity	1 Gradual Imbibition 24 hours of Immersion [1]		2 Gradual Imbibition 48 hours of Immersion		3 Gradual Imbibition 1 week of Immersion		4 Gradual Imbibition 4 weeks of Immersion	
				absorbed water %	condit. of specimen	absorbed water %	condit. of specimen	absorbed water %	condit. of specimen	absorbed water %	condit. of specimen
766	2·4356	2·6800	0·2444	1·16	no change	1·24	no change	1·48	no change	1·01	no change
767	2·2960	—	—	3·42	25	3·46	19	4·95	25	4·8	25
768	2·1650	2 6650	0·500	6·22	8	4·73	7	5·26	no change	5·97	17
769	2·1340	2·6880	0·554	7·27	25	7·22	25	9·64	»	7·14	14
770	2·0450	2·6900	0·645	8·83	no change	8·47	no change	9·01	»	10·09	no change
771	2·0630	2·6920	0·629	9·64	»	8·59	»	9·08	»	9·84	»
772	2·2690	2·5080	0·239	3·67	»	4·56	»	3·38	»	6·54	»
773	2·2510	2 6960	0·445	2·68	»	3·87	»	4·47	»	4·66	»
774	1·7530	2·6800	0·927	13·98	25	12·95	21	15·46	»	14·23	25
775	1·6110	2·675	1·064	17·56	4	18·51	9	19·17	11	20·39	6
776	1·716	2·686	0·960	11.90	7	14·51	6	16·68	7	16·13	5
777	1·803	2·701	0·898	10·02	7	10·59	13	1019	15	14·55	5
778	1·909	2·699	0·790	11·08	20	12·08	14	11·64	5	11·53	12
779	2·147	2·672	0·525	7·24	10	7·19	24	7 26	no change	7·66	7
780	1·761	2·687	0·926	12·93	7	13·22	10	14·54	8	16·57	2
781	2·235	2·687	0·452	6·08	21	7·32	no change	6 92	no change	5·95	6
782	2·401	2·699	0·298	3·80	22	9·64	»	4·00	22	4·09	7
783	2·087	2·701	0 614	7·18	16	9 69	11	9·22	8	—	1
784	2·006	2·706	0·700	11·03	no change	10·40	no change	13·67	no change	9·58	21
785	1·738	2·690	0·952	17·01	»	17·40	»	17·99	23	19·05	1
786	1·753	2·704	0·951	15·64	»	17·34	»	17·61	no change	18·69	no change
787	1·709	2·702	0·993	11·05	»	11·17	»	12·22	»	13·04	»
788	1·616	2·704	1·088	6·33	»	6·60	»	8·00	»	8·21	»
789	1·671	2·679	1·008	17·31	6	15·32	5	16·88	12	18·46	3
790	1·628	2·672	1·044	26·73	2	17·61	2	18·37	1	—	[1]
791	1·584	2·707	1·123	18·38	23	18·73	25	—	25	21·07	4
792	1·601	2·688	1·087	—	16	—	23	—	25	19·72	4
793	1·680	2·674	0 994	—	no change[1]	—	18	—	20[1]	17·96	12
794	1·628	2 675	1·047	17·03	17	17·34	20	18·69	3	20·20	4
795	1·631	2·688	1·057	15·32	25	15·51	18	17·03	21	17·86	11
796	1·506	2·685	1 179	—	16[1]	—	13[1]	—	9	23·89	1

[1] The number in the column; "condition of specimen" indicate the number of thawing processes which effected the disintegration of the specimen. For example: 9 means that the specimen under test began to disintegrate under the 9th thaw.

of the Tests. Table A.

5		6		7		8	9	
Imbibition in vacuo		Imbibition in vacuo 1 week of immersion		Imbibition in vacuo Specimen plunged into brine		Gradual Imbibition 24 hours of immersion	Gradual Imbibition 48 hours of immersion	Practical Evaluation of the stone
absorbed water %	condit. of specimen	absorbed water %	condit. of specimen	absorbee water %	condit. of specimen	Specimen plunged into brine	Specimen plunged into brine	
—	no change	2·33	no change	2·65	15	no change	no change	frost-proof
—	25	4·82	23	5·35	1	—	—	„
—	6	7·01	5	6·93	1	—	—	„
7·75	25	8·39	16	9·66	1	1	1	„
10·43	no change	10·29	12	10·35	2	1	1	„
9·07	„	9·81	25	10·99	1	1	1	sensitive to frost
6·15	„	7·03	5	6·66	1	no change	no change	frost-proof, but sensitive to moisture
2·15	„	6·09	no change	1·87	no change	„	„	frost-proof
16·82	4	17·96	1	19·16	1	„	1	„
23·26	1	23·25	4	27·78	1	1	1	„
18·24	3	18·68	4	19·92	1	no change	1	„
14·12	7	16·67	4	17·36	1	—	—	„
12·91	7	13·81	4	10·59	1	—	—	frost-proof
5 62	no change	8·63	13	5·79	2	—	—	„
17·34	3	18·07	4	17·52	1	no change	—	„
7·32	18	7·88	10	7·37	1	1	1	sensitive to frost, if the quarry water has not been thrown off
3·88	4	4·46	8	3·50	2	no change	no change	„
10 02	19	10·25	24	9·95	1	1	1	„
14·25	no change	14·33	no change	12·63	1	1	1	„
19·12	„	—	24	19·08	1	1	1	sensitive to frost
20·13	25	19·87	23	19·10	1	1	1	„
20·25	1	19·08	22	18·94	1	no change	no change	frost proof
23 39	1	19 07	24	20 81	1	„	„	„
21·64	1	22 37	1	19·87	1	1	1	„
23·09	1	—	1[1]	22·25	1	—	—	sensitive to frost
24·57	1	24·69	15	30·82	1	1	1	„
23·52	1	22·70	6	21·37	1	—	—	„
21·29	1	—	1[1]	17·51	1	—	—	„
22·00	1	23·00	6	23·01	1	1	1	frost-proof
21·96	1	22·68	11	20·82	1	—	—	„
28·57	1	—	1[1]	26·64	1	—	—	sensitive to frost

[1]) The numbers in the column "condition of specimen" indicate the number of thawing processes which effected the partial disentegration of the specimen.

Recapitulation of
Designation

Number	1 Gradual Imbibition 24 hours of Immersion	2 Gradual Imbibition 48 hours of Immersion	3 Gradual Imbibition 1 week of Immersion	4 Gradual Imbibition 4 weeks of Immersion	5 Imbibition in vacuo
766	○	○	○	○	○
767	—	—	—	—	—
768	—	—	○	—	—
769	—	—	○	—	—
770	○	○	○	○	○
771	○	○	○	○	○
772	○	○	○	○	○
773	○	○	○	○	○
774	—	—	○	—	—
775	—	—	—	—	—
776	—	—	—	—	—
777	—	—	—	—	—
778	—	—	—	—	—
779	—	—	○	—	○
780	—	—	—	—	—
781	—	○	○	—	—
782	—	○	—	—	—
783	—	—	—	—	—
784	○	○	○	—	○
785	○	○	—	—	○
786	○	○	○	○	—
787	○	○	○	○	—
788	○	○	○	○	—
789	—	—	—	—	—
790	—	—	—	—	—
791	—	—	—	—	—
792	—	—	—	—	—
793	○	—	—	—	—
794	—	—	—	—	—
795	—	—	—	—	—
796	—	—	—	—	—

Note: ○ : Specimen has stood the test.
— : Specimen has not stood the test.

Frost Tests.
of the Test.

Table B.

6	7	8	9	10
Imbibition in vacuo 1 week of Immersion	Imbibition in vacuo	Gradual Imbibition 24 hours of immersion	Gradual Imbibition 48 hours of immersion	Practical evaluation of the stone
	Specimen plunged into brine of calcium chloride	Specimen plunged into the brine	Specimen plonged into the brine	
0	—	0	0	frost-proof
—	—	~	~	„
—	—	~	~	„
—	—	1	1	„
—	—	1	1	„
—	—	1	1	sensitive to frost
—	—	0	0	frost-proof, but sensitive to moisture
0	0	0	0	frost-proof
—	—	0	1	„
—	—	1	1	„
—	—	0	1	„
—	—	~	~	~
—	—	~	~	frost-proof
—	—	~	~	„
—	—	0	~	„
—	—	1	1	sensitife to frost, if the quarry water has not been thrown off.
—	—	0	0	„
—	—	1	1	„
0	—	1	1	„
—	—	1	1	sensitive to frost
—	—	1	1	„
—	—	0	0	frost-proof
—	—	0	0	„
—	—	1	1	„
—	—	~	~	sensitive to frost
—	—	1	1	„
—	—	~	~	„
—	—	~	~	„
—	—	1	1	frost-proof
—	—	~	~	„
—	—	~	~	sensitive to frost

Note: ~ : Specimen not tested.
1 : Specimen failed at first thaw.

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XIII$_2$

NOTES ON TRASS, TRASS-CEMENT AND CEMENT-LIME MORTARS.

By Dr. techn. **Heinrich Renezeder.**

Translated from the German by H. Borns, London.

(From "Mitteilungen des Mechanisch-technischen Laboratoriums der k. k. techn. Hochschule in Wien".)

The following mixtures of mortars have been investigated in the mechanical and technical Laboratory of the k. k. Technical High School at Vienna.

1. 1·2 trass T_1 + 1·0 powdered lime K_1 + 1·75 sand S_1
2. 1·0 cement Z_1 + 1·75 „ „ K_1 + 5·25 „ S_1
3. 0·5 „ Z_1 + 0·5 lime dough K_1 + 1·5 „ S_1
4. 1·0 trass T_2 + 1·0 powdered lime K_2 + 1·0 „ S_2
5. 1·0 „ T_2 + 1·5 „ „ K_2 + 2·0 „ S_2
6. 1·0 „ T_2 + 2·0 „ „ K_2 + 4·0 „ S_2
7. 1·0 „ T_2 + 0·66 lime dough K_2 + 1·0 „ S_2
8. 1·0 „ T_2 + 1·0 „ „ K_2 + 2·0 „ S_2
9. 1·0 „ T_2 + 2·0 „ „ K_2 + 4·0 „ S_2
10. 1·0 „ T_2 + 1·0 cement Z_2 + 0·66 lime dough K_2 + + 5·0 sand S_2
11. 1·0 cement T_3 + 3·0 sand S_3
12. [1·0 „ Z_3 + 3·0 „ S_3] + [1 lime dough K_3 + + 1·5 trass T_3 + 1·75 sand S_3]
13. 1·0 (cement Z_3 + powdered lime K_3) + 3 sand S_3; $Z_3 : K_3 = 75 : 42·5$
14. 1·0 (cement Z_3 + lime dough K_3) + 3 sand S_3; $Z_3 : K_3 = 75 : 25$
15. 1·0 (cement Z_3 + lime dough K_3) + 3 Trass T_3; $Z_3 : K_3 = 75 : 42·5$
16. 1·0 (cement Z_3 + lime dough K_3) + 3 Trass T_3; $Z_3 : K_3 = 75 : 25$

17. 1·0 Roman cement R + 3·0 sand S_3
18. 1·0 Roman cement R + 1·5 sand S_3 + 1·5 trass.

Specimens were prepared from these mixtures for the determination of the strengths under tension, compression and bending, of the permeability to water, and of the elasticity.

The following strengths in kg/cm², among others, were found after three months of storing under water.

Mixture No.	Crushing strength	Bending strength	Mixture No.	Crushing strength	Bending strength
1	123·5	27·38	10	433 3	39·19
2	143 8	32·18	11	233·0	56·74
3	138·9	29·60	12	168·5	38·61
4	152 7	33·69	13	189·3	37·56
5	128·2	32·53	14	173·7	37·44
6	103·5	22·93	15	311·5	31·01
7	137·5	36·50	16	287·6	23·98
8	120·3	26 03	17	137·2	26·32
9	86 3	26·09	18	40·5	10·52

The elasticity was determined under compression stress in prisms, 16 cm in height and 4 by 4 cm in cross-section.

The following moduli resulted:

Mortar No.	Calculation based upon the total compression (E min.)	Calculation based upon the purely elastic deformation (E max.)
1	35·800	49·700
2	70·500	91·100
3	86·400	93·600
4	86·100	162·000
5	63·500	124·800
6	68·400	110·500
7	47·000	63 900
8	74·200	90 100
9	36·700	81·800
10	113·000	145·700
11	103 500	141·100
12	63·600	102·400
13	59·900	68·400
14	55·800	89·500
15	70·000	91·700
16	56·700	67·200
17	36·200	59·000

The adhesion was only determined for the mortar mixtures 1, 2, 3, 4. The relatively most favourable results were obtained with the trass mortars. The permeability to water was ascertained with slabs of 5 cm thickness; the following volumes of water measured in cm^3 passed through the slabs per hour under a pressure of 2·5 atmospheres.

Mortar No.		Mortar No.	
1	0·51	10	2·1
2	3·4	11	2·1
3	2·1	12	0·9
4	0·15	13	1·1
5	0·38	14	1·4
6	2·0	15	0·0
7	0·25	16	0·05
8	1·1	17	18·3
9	2·3	18	27·6

Remarks and Conclusions.

Better results were obtained when the calcic hydrate was applied as a powder, which was mixed with trass in the dry and then only wetted, than when the lime had previously been watered in the pit.

The samples of the mortar mixtures 12, 13 and 14 show a very satisfactory agreement in their several tests.

Though the addition of lime to Portland cement somewhat decreases its strength, il reduces the rigidity of the cement sand mortar.

The author arrives at the following conclusions:

1. When mixed with the proper proportions of calcic hydrate Portland cement mortars appear, as regards strength, elasticity and permeability to water equivalent to the trass cement mortars which the late Professor Intze recommended for the construction of dams.

2. Portland cement can be rendered more waterproof by substituting trass for sand.

3. The adhesion appears better with trass mortars than with Portland cement mortars.

4. As regards the addition of calcic hydrate, a well-slaked powdered lime answers better than lime in the doughy condition.

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XIII 3

CONTRIBUTIONS TO THE METHODS OF TESTING THE ELASTIC ALTERATIONS IN THE LENGTH OF CONCRETE.

By Dr. Ing. **Béla v. Bresztovszky**, Budapest.

Translated from the German by Dr. H. Borns, London.

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1. Introduction. When the load is taken off a specimen, whose length has been altered by an axially acting force, one portion ($= \lambda_e$, elastic alteration) of the resulting change in length (λ) will disappear, another portion ($= \lambda_m$, permament set) will remain, and λ must of course be equal to $\lambda_e + \lambda_m$. When we determine two of these quantities for any force P_i, which lies between zero and the breaking load, and plot the results on some system of co-ordinates — in which the ordinates represent the forces, and the abscissae the alterations in length — we obtain the stress-strain diagram of the total change, comprising the elastic alteration and the permament set. That the various elasticity tests which have been published[1]) differ in their results, is explained by the different méthods in which the stress-strain diagrams are determined. In some of these tests the loads were repeated; others were conducted entirely without repetitions. Frequently insufficient attention is paid to the peculiarities of the permanent set which experimenters try to eliminate.

My tension tests have been conducted in the laboratory of Professor v. Nagy, partly with the object of studying the influence

[1]) Compare the researches of Bauschinger, Durand-Claye, Hartig, Souleyre, Österr. Gewölbeausschuß (Committee on Vaults), v. Tetmajer, Joly, v. Bach, Considère, Feret and others.

of repetitions, and partly for the purpose of obtaining stress-strain diagrams: I. with repetitions, II. without repetitions[1]).

2. Specimens and General Arrangements. All the 80 specimens were concrete prisms of square cross-section, length of side 15 cm, length of specimen 60 cm, length between gauges 43 cm. The specimens were prepared from four different mixtures in iron moulds and suitably treated until submitted to the tests. The experiments were conducted at ages of 1, 2, 6 weeks, 5, 9, 11 to 17 months and $1^1/_2$ to 2 years, partly with a 100 ton Werder-machine, partly with a 500 ton press. Readings were taken with a Bauschinger mirror apparatus, tenths of a micron being estimated.

1. Tension Tests with Repetitions.

3. The Tests. The load was in every case raised from an initial value P_0, as a rule approximately 1 ton ($= 4{\cdot}44$ kg/cm²), with very hard materials 5 tons, within one minute to the final value P_i. The removal of the load was effected within the same interval. The rate of increase in the load was therefore greater for the larger forces. Load alternations were made 30, 50 to 100, and, when the lengths were not determined, frequently from 200 to 300 times. At first I determined the alteration in the length for each single load, later only after 5 or 10 repetitions — since the additional strain for every single load became very small. After completing a series of experiments with repetitions the specimens were submitted to loads such that the force increased uniformly (by 1 ton per minute); in this case the alterations in length were determined for each additional ton.

4. Results. a) It is usually assumed that a number of load alternations will transform the material into a constant state, in which the material turns "perfectly elasctic" and in which the λ, λ_e, λ_m attain certain limiting values. When we plot curves in which the abscissae are the increments $\triangle\lambda$, $\triangle\lambda_e$, $\triangle\lambda_m$, and the ordinates the number (n) of repetitions, these curves, which we will briefly call repetition curves should become parallel to the n-axis, when the limit values are attained. The resulting curves (e. g. Pa 1, H 20, H 38) show that the increments become smaller with increasing n, but that a constant condition is not reached with

[1]) Accounts of most of these tests have appeared in the Zeitschrift des Ungar. Ingenieur- und Architekten-Vereines "Közlöny", 1907 and 1909.

from 30 to 100 repetitions of the force which constituted from $^1/_{10}$ to $^3/_4$ of the breaking load. The existence of such limit values would hence in general appear to be doubtful.

b) When we construct the stress-strain diagram for the uniform load increase after the repetitions (as mentioned in section 3 of this paper), we obtain a curve which is essentially a straight line up to a P_a = limit, that is to say, the already loaded body displays a certain proportionality between the force and the alteration in length. The ordinate of the P_a = limit increases with the number of previous load alterations; it may even exceed the magnitude of the repeated force. The angle of inclination (ψ) of this straight line diminishes with an increasing number ot repetitions; the elongation coefficients $\alpha = \frac{1}{E}$ will therefore grow correspondingly.

II. Tension Tests without repetitions.

5. The Tests. In order to separate the elastic component and the permament set, Professor A. Rejtő interrupts the loading process (by uniformly increasing loads applied without shock), when a certain force P_i has been reached; he then takes off the load, again applies a greater load, and so on. The curves obtained after removing the load start as straight parallel lines, by means of which the two components can be distinguished. Proceeding in this way, I increased the load in my experiments from the initial load P_o (compare section 3) uniformly up to P_1, without shock, and then reduced the load down to P_o again; $P_2 > P_1$ was afterwards applied, and the operation continued until fracture ensued. The constant rate of increase of the load was in the case of hard materials, 2·5 tons (about 11 kg/cm²) per minute, and in the case of less hard materials 1 ton per minute. Readings on the mirror apparatus were taken at the end of each minute; thus the alteration in length was ascertained not only for the beginning P_o and the end P_i of each load application, but also for each intermediate load of one ton.

6. Results. a) The plate illustrates some of the stress-strain diagrams secured in this way. The experiments concern the materials H 35, H 29, H 11, H 14, H 25 and P 2, the breaking loads being respectively 11·5, 17, 20, 26, 62·1 and 101 tons, corresponding to 51, 75·5, 88·9, 115, 276, 448 kg/cm². The fully drawn lines join the experimental points, the dotted oblique lines indicate the removals

of the load, the horizontal lines fractures. The forces P are marked in tons (t), the contractions in microns.

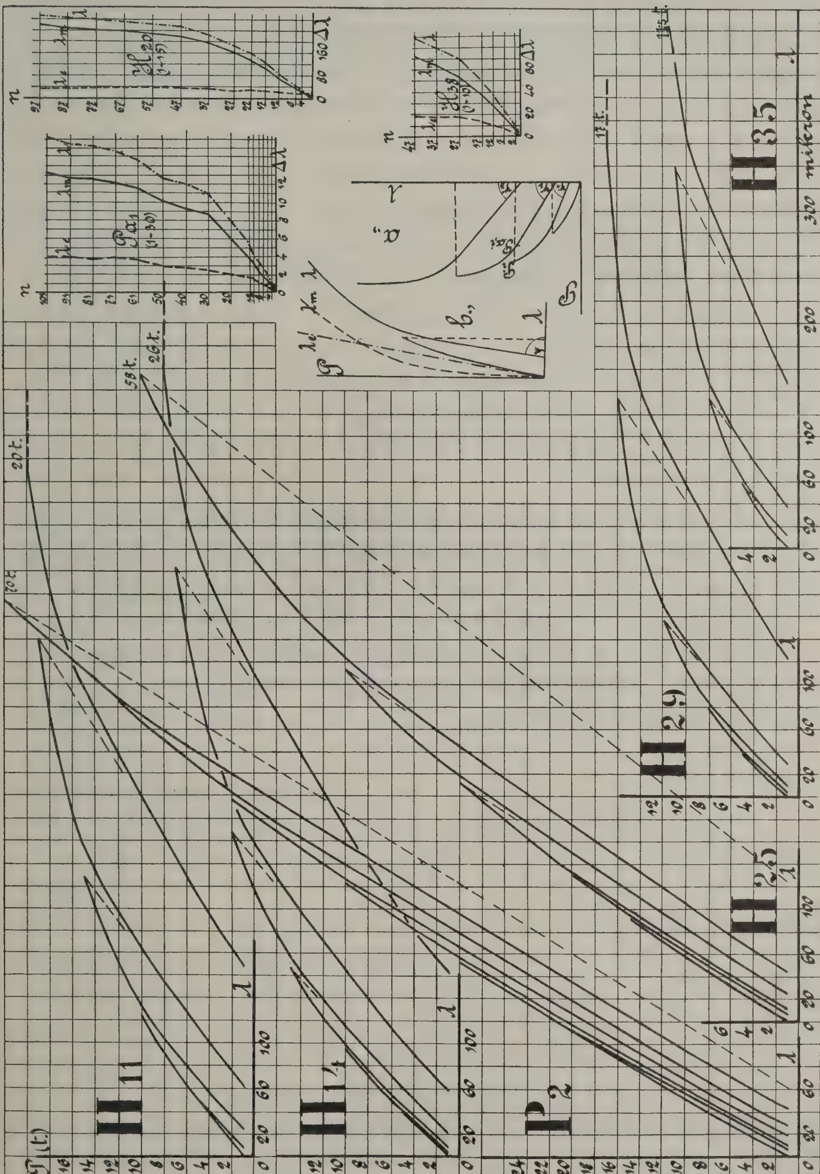
These specimens had not been stressed before the tests. The stress-strain diagrams are convex curves when looked at from the P axis; on removing a load the diagrams starts as a straight line which passes into a convex curve. There was hence no proportionality between P and λ at first; such a proportionality extending up to a certain limit, $P_a < P$, was however called forth already by the first loading. After each removal of the load we have, so to say, to deal with a new material, which can do less work than it could perform in the previous condition, and which moreover possesses an initial proportionality, an initial hardness.

b) When we compare the directions of the several straight lines, we observe that they diverge considerably from one another with less hard materials (e. g. H 35, H 29, etc.) and that they become more horizontal with increasing force. In harder materials (e. g. H 25, P 2) the lines are almost parallel to one another. It follows that the elongation coefficients (α) increase in materials of small hardness with increasing force, while they may be regarded as constant in hard materials. The latter assumption appears all the more justified as the difference in the α values was always found to be smaller in a hard material, than in two materials produced from the same mixture.

c) Loads which remained below a certain limit of proportionality P_a, already established, yielded relatively very small permament sets. When we neglect these components, we can regard the straight line portions of the curves which, in the strict sense, are the stress-strain diagrams of the total contraction (λ) as representing exclusively the elastic contraction (λ_e). In other words: below a certain limit of proportionality, previously attained already, the elastic alterations in length are proportional to the forces.

The elongation coefficient of the elastic alteration in length (α_e) can be calculated from the angle (ψ) which the straight line makes with the λ-axis. For a material of small hardness we have hence diverse α_e values, which will be the greater, the higher the respective P_a limits; for forces below the P_a limit the α_e will be

constant. With hard materials we may substitute the single value (α) for the various α_e without falling into any essential error.



7. **Conclusions.** a) When we compare the angles of inclination resulting from the series of experiments I and II, we find that — owing to the want of homogeneity in the material — there is a greater difference between the angles of two specimens, simultaneously prepared from the same mixture, than between the angles corresponding to repetitions. From the practical point of view it is therefore simpler and also justified, if we accept that figure as the coefficient of elongation which results from the tests conducted without repetitions under a uniform increase of the load without shock.

b) The concrete which has been submitted to these tests therefore displays the following regularities:

1. In the case of the material of small hardness, in the illustration: a), the law of purely elastic contraction may, with sufficient accuracy, be expressed by Hooke's law. The coefficient of elongation $\alpha_{e,i}$, which is constant below the limit $P_{a,i}$, depends upon the force P_i which caused the proportionality.

2. In the case of the harder material, in the illustration: b), the law of purely elastic contraction (λ_e) may be expressed by Hooke's law, in which the elongation coefficient retains a constant value almost up to fracture.

3. The law of the permanent contraction (λ_m) is in both cases represented by curves which are convex as viewed from the P-axis.

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XIV1

OUTLINES OF SPECIFICATIONS FOR THE SUPPLY OF OILS FOR TECHNICAL APPLICATION.

Report by the President of Commission 39, Dr. **Max Albrecht**, of Hamburg.

Translated from the German by H. Borns, London.

A resolution of the Brussels Congress referred the study of the Problem: "Principles of Specifications for the Supply of Oil for Technical Application", to an International Commission which constituted itself as follows in the beginning of the year 1908.

President: *Dr. Max Albrecht*, Hamburg.

Vice-President: *E. Camerman,* Ingénieur en Chef au Laboratoire de l'Arsénal de l'Etat, Malines, Belgium.

Members: *A. Jakobsen,* Chemist to the Royal Danish State Railways, Copenhagen B.

Dr. Holde, Professor, Groß-Lichterfelde, Berlin.

Hav. Buch, Engineer to the Norwegian State Railways, Kristiania.

Dr. R. T. Glazebrook, Director of the National Physical Laboratory, Teddington, England.

P. Breuil, Chef de Section des Essais de Métaux au Laboratoire du Conservatoire des Arts et Métiers, Paris, 292 Rue St. Martin,

H. Baucke, Amsterdam, Da Costakade 104.

H. Cattaneo, Aide du Directeur de l'Institut expérimental des Chemins de Fer de l'Etat, Rome.

Josef Grossmann, Austrian Nordwestbahn, Vienna.

R. Kind, Messrs. Kind & Herglotz, Aussig a. Elbe, Austria.

Gebrüder Sulzer, Engineering Works, Winterthur, Switzerland.

A. H. Gill, Professor at the Massachusetts Institute of Technology, Boston,

H. A. Julius, Engineer for designs and Tests, Government Railways (West-Australia Dept.) Midland Junction, Western Australia.

Owing to the late constitution of the Commission and the need of discussing and fixing the method to be adopted in a general meeting — which, it is intended, will be done at the Copenhagen Congress — the Commission has not as such been able to enter upon its duties.

The President of the Commission has, however, compiled a summary of the "Principles of the Testing of Mineral Lubricating Oils", adopted by the German Verband für Materialprüfungen der Technik, to serve as a basis for the work of the Commission. This summary has been published for the guidance of the members during the deliberations.

Extract from the Principles of Testing Mineral Lubricating Oils.

(As accepted by the German Verband für die Materialprüfungen der Technik in 1907.)

A. Chief Tests.

I. Transparency. The transparency of the oil in a thin stratum is to be determined by letting the oil run off from a glass surface.

II. Specific Gravity. The density is determined by the usual methods (with the aid of officially standardised areometers, pyknometers, the Mohr balance, or the alcohol float method). The standard temperature is $+15^0$ C., the unit of mass water at $+4^0$ C.

III. Consistency of Cylinder Oils and similar Thick Oils at ordinary Temperature. For ordinary works practice it is sufficient to determine the consistency in a test tube, 15 mm in diameter, filled to a height of 50 mm. A first test is to be made without heating, a second test after heating the oil for 10 minutes in a bath of boiling water. Immediately after this preliminary examination both samples are for one hour kept in a water bath at the temperature, which will afterwards have to be borne in a practical service. The test tube is then inverted and the consistency determined.

IV. The Fluidity (Viscosity) has to be determined with the aid of Engler's apparatus (compare Holde, Untersuchung der Mineralöle etc., Berlin, 1905: Julius Springer, p. 100). In the case of thick oils the test may be abbreviated by reducing the amount of oil whose delivery into the receiving flask is watched to 50 or 100 cm^3. The tests have to be conducted: for machinery and railway car oils at + 20 and 50^0 C., for cylinder oils at + 50 and 100^0 C. Oils containing water have to be dehydrated before the examination.

V. The Behaviour of liquid Lubricants in the cold is to be determined either by the simple test-tube method (compare Holde, p. 131) or, in a U tube under determination of the coefficient of free flow.

The samples have to be tested, not only as supplied, but also after having been heated for 10 minutes up to about 50^0 C.

VI. Flash Point. Wherever the highest accuracy is desired, the Pensky-Martens apparatus has to be applied; in other cases the open cup, suitably fitted with mechanical movement for the test-flame and adjustable burner after Marcusoon (compare Holde, p. 144).

VII. Chemical Tests.

a) Acidity (free acid). The methods in use (Holde, p. 154) are to be retained, and the standard of acidity shall remain the sulphuric acid anhydride.

b) Solubility in Petrol and Benzene. Dark oils shall entirely be soluble in benzene. The asphalty constituents are deduced from the solubility of the oil in 40 times its bulk of pure petrol spirit, the density of which ranges from 0.695 to 0.705 and the boiling point from 65 to 95^0 C. The solution in this petrol is to stand for 24 hours under exclusion of direct sunlight at a temperature of from 15 to 20^0 C.

The alcohol-ether method (Holde, p. 20) shall particularly serve for comparative and identy tests.

c) Estimation of Fatty Oils. The quantitative test for fatty oils is made by heating 3 or 4 cm^3 of the oil to be examined together with a piece of caustic soda or of metallic sodium, for a quarter of an hour, up to about 240^0 C. in a paraffin bath. When cooled to ordinary temperature, the oils will, in the presence of

fatty oils, afterwards shew gelatination or soapy froth, or both these features.

The quantitative proportion of fatty acids is ascertained with the aid of the saponification coefficient or gravimetrically after Spitz and Hönig.

d) Estimation of Resin Oil. In the test for resin oil a small sample of $5 cm^3$ is well shaken with sulphuric acid of density 1·62. Resin oil will be present when, after the separation of the layers, the acid does not look yellow or brown, but shews the characteristic red colour. For the quantitative determination the oil has then to be extracted (after Storch) with alcohol of 96 per cent and submitted to a polarisation test etc.

e) Percentage of Water. With oils, which flash below 240^0 C. in the Pensky apparatus, the moisture test is conducted by determining the losses in weight suffered by two samples of about the same mass (10 or 15 grammes) of the original and the dehydrated oil, when heated in glass dishes on the boiling water bath until all froth formation has ceased. The difference in the losses of weight of the two samples gives the percentage of water in the original oil. The oil is dehydrated before this heating by being shaken with calcium chloride in an Erlenmeyer flask and subsequent filtration through a dry filter.

f) Alkalis and Salts are determined in aqueous extracts of about 100 grammes of oil in the usual manner. This applies also to naphthene salts which may further be determined by direct incineration.

g) The Caustic Test is used for determining the degree of refining and paiticularly any naphthene salts, dissolved in oil. Equal volumes of oil and of caustic soda of 3^0 Bé. are shaken together; no emulsion of oil and caustic should become discernible at the boundary after the shaking; else such salts will be present.

B. Supplementary Tests.

The determination of the fire point, the distillation tests, the determination of the amount of volatile constitutents, and the paraffin estimation may as a rule be dispensed with in the examination of lubricating oils. The German Association has, however, laid down the principal rules also for these tests.

The principles of testing Illuminating Oils, Gas Oil, Oils for Cleaning Purposes, Petrol and Parafin.

A. Illuminating Oils.

I. External Characteristics. The colour should be determined with the aid of the Stammer colorimeter.

The capilarity can suitably be ascertained with the aid of Ziegler's petroleum viscosimeter, as modified by Ubbelohde, provided with a narrow orifice.

II. The flash point should be dextermined with the aid of Abel's apparatus.

III. Distillation Test. The continuous distillation is effected in an Engler apparatus of glass (Compare Verhandlung des Vereines für Gewerbefleiß, 1887).

The distillates which pass at temperatures up to 150^0, 150 to 200^0, 200 to 250^0, 250 to 275^0, 275 to 300^0 C are separately to be collected, and the proportions of the constitutents whose boilings points lie above 300 C. are to be ascertained by difference. The boiling is said to commence when the first drop is seen to fall from the end of the cooler in Engler's apparatus. The fractionation will in general be conducted volumetrically.

IV. Degree of Refining.

a) The acid test is to be conducted by titration with at least 100 cm^3 of petroleum, which is dissolved in alcohol and ether.

b) In the case of Russian Petroleum the soda test should be applied as dcscribed in Muspratt's Technische Chemie, 1898, p. 2234. When the test is affirmative, the presence of napthene salts is to be established by the incineration of 1 litre of oil which had previously been reduced, by distillation, to a volume of about 30 cm^3.

c) When equal parts of petroleum and sulphuric acid of specific gravity 1·75 are shaken together, the acid shall not turn more than very slightly coloured.

d) For the detection of unsaturated hydrocarbons the oil is shaken with sulphuric acid of density 1·83.

V. Sulphur Percentage. The sulphur test must be quantative by the method of Heussler, Zeitschr. f. Angewandte Chemie, 1895, p. 285; Engler, Chemiker-Zeitung, 1896, p. 1897.

VI. Combustion Tests. The unit of light intensity is the standard Hefner candle of the amyl acetate lamp.

Exact photometric determinations are made with the Lummer-Brodhun photometer head; for other examinations a grease spot photometer is used.

The lamps should in general be fitted with round burners of 14'''; in the case of oils which require an ample supply of air for their complete combustion, reform round-burners (Schuster-Baer) should be used. The burner test is as a rule to last 6 hours. During the first quarter of an hour the flame should be turned up as high as possible; a quarter of an hour before the first bench measurement the burner should once more be turned up, and then be left to itself, entirely without any regulation. Photometer readings shall as a rule be taken after the expiration of two hours, and again at the end of the test. The crust of the wick is carefully to be removed and to be weighed. A fresh wick is to be used for every kind of oil. In general the total consumption of oil will be ascertained by weighing the lamps before and after the test. In addition to the mean light intensity and the total oil consumption the consumption should also be stated per candle per hour. It should also be ascertained, whether the oil burns uniformly and the composition of the oil remains unaltered by the combustion test. For this purpose the residue, which remains in the lamp after burning half the oil, is to be tested for specific gravity and boiling point limits, and the ordinary distillation test is also to be repeated after the burning.

B. Gas Oils.

The determinations of the specific gravity, the fluidity and the flash point in the Pensky-Martens apparatus are to be effected in the same manner, as with lubricating oils.

The distillation test is likewise to be conducted in the same manner, except that the fractionations are to be collected at intervals of 50 deg. cent.

The congelation is determined in the usual manner in a test-tube.

In the Creosote test, 100 cm³ of oil are shaken with 100 cm³ of caustic lye of 6° Bé for five minutes at ordinary temperature. The diminution in the volume indicates the percentage of creosote.

The Sulphur percentage is determined after Carius or after Gräfe (Zeitschr. f. Angewandte Chemie, XVII, Nr. 19).

The determination of the Gas Figure should in general be effected exclusively with the aid of apparatus of actual works dimensions.

The resulting percentage of gas is only valid for the apparatus and the working conditions, under which it was obtained.

The Light Intensity is to be measured with a burner consuming 35 l/hour. The measurements are to be effected as in the case of petroleum, and the gas consumption is to be determined with the aid of a standardised gas meter.

C. Oils for Cleaning Purposes.

Oils intermediate between illuminating oils and gas oils are designated by this term.

The specific gravity, the fluidity and flash point (the Pensky-Martens apparatus) serve for the identification of the sample and should be determined as in the case of lubricating oils; the distillation test is effected as with Gas oils.

D. Petrol.

The determination of the specific gravity is carried out as with other mineral oils. For the distillation test the Engler glass apparatus is to be recommended as with petroleum. The degree of refining can be judged from the colour, the smell and the behaviour of the oil in the presence of concentrated sulphuric acid.

Chemical Tests. In the qualitative tests for coal-tar benzene, the solvent power of the sample with regard to an asphalt which had been extracted with petrol benzine is made use of (Holde, pp. 185 to 186); the subsequent quantitative analysis is based upon the determination of the portion soluble in fuming sulphuric acid.

The detection of carbon bisulphide depends upon the conversion of this impurity into potassium xanthogenate; oil of turpentine is recognised by the bromine reaction, or by its conversion into nitrosylchloride. Products (fats) of high boiling points are determined by evaporating 100 cm^3 of the petrol in a weighed dish on the water bath and by weighing the residue.

E. Paraffin.

By the term Paraffin are meant hydrocarbons resulting from the distillation of bituminous raw materials.

Specific Gravity. The specific gravity test is essentially an identity test and may be carried out at ordinary temperature with the aid of the alcohol float method, or at 100⁰ C. with the aid of the Mohr balance.

The Congelation point is fixed either according to Shukoff (Chemiker Zeitung, 1901, p. 1111) or according to Halle (Böckmann-Lunge, chem.-techn. Untersuchungsmethoden, 3, p. 153, 1900). Beginning and completion of the melting can further be watched in a capillary tube. The contents in paraffin is ascertained after Holde (Holde p. 21); the sample is perviously freed from mechanical impurities and from water.

F. Paraffin Candles and Mixed Candles.

As regards these materials, the tests concern:

1. The material from which the candles are said to have been made, and

2. the behaviour of the candles during use.

As to 1. the point of congealation, the saponifiable constitutents, and the non-saponifiable constitutents should be determined, or in the latter case, the contents in methyl, ethyl, amyl alcohols, and acetone and the presence of anilides;

as to 2. the illuminating value has to be ascertained and the bending test to be performed.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

V[TH] CONGRESS, COPENHAGEN 1909.

XV1

MECHANICAL TESTS OF CAOUTCHOUC AND TISSUES.

By M. **Pierre Breuil**, Paris.

Translated from the French original by Arthur R. Liddell, Charlottenburg.

Abstract. [1])

The author believes he may be of service to those interested in the subject of mechanical tests on caoutchouc and tissues by devising two apparatus, which enable such tests to be made.

The first of these is a dynamometer, which supplies the means of making the following tests:

Cold or hot tensile tests, applied slowly or alternating in direction.

Cold or hot compression tests, applied slowly or alternating in direction.

Alternating bend tests.

Wearing, perforation and plasticity tests.

In this dynamometer, the appliance which produces the strains, is a screw. This can be adjusted to two speeds when it is to produce static strains, and by means of a connecting-rod actuated by an eccentric, when it is to produce alternating strains. The applianee which measures the strains is a spring, that is placed under compression, and the deformation of which is at most one third of that which it can withstand without its coils touching one another.

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1) The original report is published in the "Supplements to the Congress Papers".

By means of a pointer which follows the deformations of the spring, the diagram of the tension or compression of samples undergoing test may be traced on a recording cylinder controlled by a wire which follows the elongations and contractions of the test samples.

Cold or hot tensile or compression tests may be made, the samples being placed in suitable troughs containing cooled or heated fluid.

For the alternating bend tests the sample is fixed between the jaws of the dynamometer, and made to bend, first to one side of its axis and then to the other, by means of a connecting-rod of variable eccentricity.

For the wearing tests the eccentric of the apparatus is provided with a wooden disc covered with an emery-paper wearer, and the samples are made to bear against the disc with a known pressure applied by a little lever appliance.

The samples to be submitted to wear are attached to the holding appliance of the dynamometer, which is connected with the spring that measures the strains; they then place the latter under tension, and this tension, when set against the pressure which causes the samples to bear against the wearing-disc, gives the coefficient of wear of the material under test.

By means of the compression-lever it is possible to perforate strips of material, which are grasped by the jaws of the apparatus. Finally by the help of a little appliance fitted with cylinder and piston, which is placed between the compression surfaces of the machine, the plasticity of soft bodies may be measured by enclosing these in the cylinder and obliging them to ooze through an orifice in the bottom of the latter.

The object to be served by the second apparatus is the measurement of the elasticity of a flexible or hard body and the hardness of flexible bodies only. It consists of a small vice, between the jaws of which the pieces to be tested are inserted. On the upper jaw of this vice a tube with a graduated glass may be screwed, with a photographic iris shutter.

On the latter is placed a steel ball of 5 mm or 10 mm in diameter, which is allowed to fall freely on the test-sample when the shutter is opened. The height to which the ball bounces,

compared with the height of its first drop, is a measure of the excellence of the elasticity of the material under test.

This apparatus also lends itself quite as well to the testing of hard bodies (metallic and non-metallic) as to that of soft ones.

If, in place of the glass tube, a brass one bearing a spring and a steel pointer be screwed to the jaw, it is possible, by causing the point to penetrate the flexible body and measuring the strain set up by the production of a given impression by help of the spring, to obtain a precise idea of the hardness of the body.

With the two apparatus described, the author has made a considerable number of tests, the particulars of which he has given in his original article, but which cannot be reproduced here.

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□ VTH CONGRESS, COPENHAGEN 1909. □

XV2

CONTRIBUTIONS TO THE QUESTION OF THE MECHANICAL TESTING OF INDIA-RUBBER.

On the influence exercised by the shape of the sample on the results of tensile-test by **K. Memmler** and **A. Schob.**

Abstract[1]) from the "Mitteilungen des Kgl. Materialprüfungsamtes, Groß-Lichterfelde".

Translated from the German by A. R. Liddell, Charlottenburg.

The experimental work was undertaken at the suggestion of the Director of the Amt, A. Martens, in order to verify the influence of the shape of the sample on the results of tensile tests and to find out a standard shape of sample for the testing of india-rubber.

In the following only the conclusions come to in the work are reproduced. For the considerations on which they are based reference must be made to the work itself (Mitteilungen, number 4).

The conclusions are based on extensive experiments with 6 different kinds of rubber (I, II, and IV to VII) which, as regards the properties displayed by them, vary considerably one with another, and which may be regarded as typical examples of a large number of rubbers met with in commerce.

A. Ring-shaped test-body.

1. The ring-shaped samples can be made with ease and with sufficient exactness of shape.

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[1]) Extra copies of the complete work in German will be provided at the Congress (Section C.)

2. The insertion of the ring-sample in the tensile-test machine and the making of the tensile-test itself are considerably more simple and more reliable than the like operations on the bar-shaped samples.

3. When the test is conducted in the Schopper machine, the ring test, after the insertion of the sample and the setting to work of the machine, requires no watching during the experiment, and is therefore more convenient and cheaper in its action (saving in the time of the experimenter) than the bar test, in the applications of which constant attendance is necessary, because the gripping-jaws have to be tightened up several times during the experiment, and the measurement of the elongation is a much more difficult matter.

4. For general introduction, the ring test is more suitable, because it is more easy to agree upon a standard test for a ring-shaped sample than for a bar-shaped one; with the bar-shaped sample the individual peculiarities of the rubbers often cause trouble.

5. In the tensile experiment the ring test exhausts the extensibility of the material to a greater degree than the bar test.

6. In contra-distinction to the bar test, the ring test is generally applicable for india-rubber, especially for kinds with high degrees of extensibility, for which the bar test becomes useless because of the fractures frequently occurring in the bar heads.

7. There were no marked differences in the classification of the different grades of rubber tested, whether it be based on the ring- or on the bar-test, provided that fracture did not take place in the bar-heads, as in the case of the highly extensible materials.

8. Any differences there may be between the strengths of a sheet of rubber in the longitudinal and transverse directions respectively, form no obstacle to the application of the ring-shaped sample; for as regards strength and extensibility the weakest point in the sheet will be more easily and rapidly determined by its help, and in the great majority of cases this is much the most interesting feature of the practical rubber test.

9. Alteration undergone by the material as a result of previous applications of load can be more sharply recognised with the ring sample than with the bar sample.

B. Barshaped Sample.

1. The influence of the bar shape on the ultimate tensile strength, is not clearly recognisable, unless bars without heads (barshape A) are made use of.

2. The magnitude of the gauge length has no influence on the measurement of the elongation when the end-marks lie within the prismatic part of the bar.

3. To ensure the exclusion of all influencing of the determination of the elongation, the end-marks for its measurement must therefore lie in the prismatic part of the bar.

C. Characteristic Properties of the 6 kinds of Rubber tested.

1. In order to verify differences of a regular nature between the strengths and elongations of rubber sheets in the longitudinal and transverse directions respectively, considerably more tests would have been necessary (except in the case of No. VI), since the results of individual tests are rather discordant.

2. Tests on a still more extensive scale are also necessary to gain reliable information as to the characteristic shape of the curve of elongation for india-rubber. Elongation appears in general to fall off with increase of load.

3. The duration of the application of the load appears to exercise a high degree of influence on the values for ultimate tensile strength and elongation. In a case of a load continuously applied for 30 minutes, some of the tests failed under a stress only half as great as the ultimate stress found by rapid application of the load.

4. The subsequent elastic action (shortening) on the removal of the load showed considerable differences between the different kinds of rubber I, II, and IV to VII. The simple tensile test, then, may suitably be supplemented by tests of permanent elongation and subsequent elastic action.

5. With the exception of one of them (No. VI), all the kinds of rubber tested have, according to the results of the tests with ring samples, experienced reductions of strength and elongation by reason of previous applications of load.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

V^TH CONGRESS, COPENHAGEN 1909.

VI1

INFLUENCE OF INCREASED TEMPERATURE ON THE MECHANICAL QUALITIES OF METALS.

Official Report by Prof. **M. Rudeloff**, Groß-Lichterfelde.

Translated from the German by A. R. Liddell, Charlottenburg.

The alterations of their strength properties which accompany the variations in temperature of the metals must be taken into account not only by the technologists in their manipulation (forging, rolling, etc.), but also by the designer in the choice of their dimensions; they often even form the deciding factor in regard to the application of the materials to definite purposes. In view of their great practical importance, it is not to be wondered at that the first endeavours to determine them by means of strength-tests were undertaken at a remote period. Thus Tremery and Proirier-Saint-Brice[1]) so early as 1828 established the fact that the tensile strength of hammered wrought iron, which at ordinary room-temperature was 43·5 kgs. per sq/mm, fell at a red heat to 7·8 kgs per sq/mm. As may be seen from the summary of literature given at the end of this report, an imposing series of investigations bearing upon the influence of temperature are now available. That these extend down to the most recent times, is due not only to the fact that a constant succession of new materials has to be investigated, but to a great extent also to the circumstance that the earlier results obtained have to be checked again in the light of advances made in testing-technics by the aid

[1]) See Summary of literature at the end of this report.

of improved appliances and with due regard to circumstances which are shown by present-day knowledge to exercise their influence on the results.

In the following the attempt will be made to collect the results hitherto in existence, so far as they are known to the author, into separate groups according to the materials. The methods applied and their influence on the results may, however, be discussed beforehand.

In most of the investigations the method of determining the influence of temperature was that of the tensile test; side by side with the latter the jogging test is occasionally met with, and recently the Brinell ball-pressure test has been successfully applied for the determination of alterations of hardness (36), (38). Among the conditions under which subsidiary influences may have an effect are the following:

1. The creation and determination of the testing temperature (the testing arrangements).

2. The shape of the test-sample and its insertion in the strength-testing machine.

3. The rapidity of application of the load.

4. The method for the determination of the alterations of form (elongation) during the experiment.

5. The state of manipulation of the test-sample material.

1. The testing arrangements.

The oldest method used for the production of testing temperatures higher than those of an ordinary room was that of heating the sample in a stove or in a hot bath, which was followed by the test in air.

To counteract the effect of the gradual cooling of the sample as far as possible, recourse has been had to the expedient of conducting the test very quickly (Kollmann [9]). Determinations of elasticity are here altogether out of the question, since the time is too short for the attainment of the increase of elongation accompanying additions to load or stress. But the final values of the ultimate elongation and ultimate strength are in the highest degree unreliable, the more so that, at fracture, the bar is heated inside much more than outside, and because the influence of the rapidity of application of the load meanwhile exerts its influence.

The method employed by Kollmann — that of heating a second identical sample side by side with the tensile-test sample in the same stove and determining the initial temperature t_a calorimetrically and the final temperature t_e of the test bar either by means of a previously determined cooling-curve or by calorimetric means from the fracture, and then regarding $(t_a + t_e)\, ^1/_2$ as the testing temperature — does not suffice for the removal of these drawbacks.

In more recent tests general resort has, probably for this reason, been made to the use of the hot bath, in which the

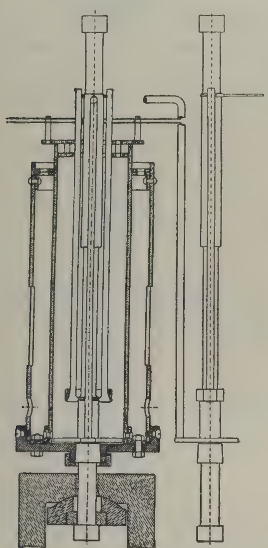


Fig. 1.
The Martens Fluid Bath with Mirror Apparatus.

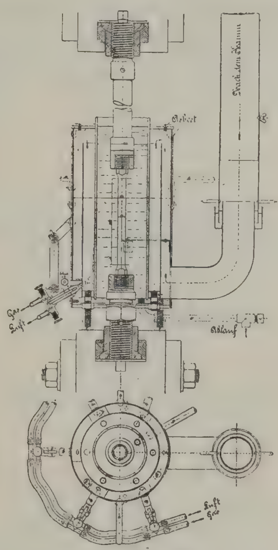


Fig. 2.
The Bach Fluid Apparatus.

sample is immersed for the whole duration of the test. A distinction must be made between fluid and air or gas baths.

For the fluid baths the material is to be so chosen that the test-piece is neither attacked by, nor able to alloy with it. In view of this, use is made of water up to a temperature of 100° C., of paraffin up to 200° C., and of mineral oil up to 350° C. For higher temperatures recourse is had to salt or metal baths. Very good results have at the instance of the Physikalisch-Technischer Reichsanstalt of Charlottenburg, been obtained

at 350 to 600⁰ C. with a mixture of equal parts of nitrate of potassium and nitrate of sodium [23]. Baths also of lead-and-tin and of pure lead have, at temperatures of from 300⁰ to 400⁰ C. and test-duration up to 2 hours, been used with thorough success in the testing of metallic alloys [14]. The heating of the baths is effected either by gasjets, which are arranged below the stove (see Figs. 3 and 7), above it (Fig. 8), and at its sides (Figs. 1, 2 and 10), or by electricity (Figs. 6 and 9).

In the case of tensile tests in upright testing machines in which the test sample is set vertically, it is advisable to lead a tension-rod from the lower gripping appliance through the bottom of the hot bath (stove), on the Martens system (11) (Fig. 1), and let it bear on a closely fitting conical shoulder on the rod (see

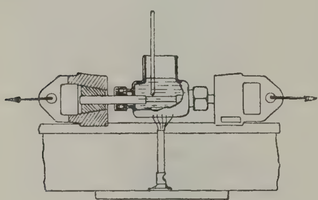


Fig. 3.
The Unwin Fluid Bath.

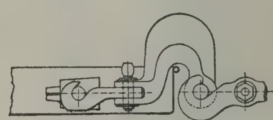


Fig. 4.
Connection between the Test-Sample and the Load-Measuring Appliance on the Martens System.

also Figs. 2 and 9). From above an exactly similar rod is then made to pass into the stove through the lid of the latter. The tensile test sample is inserted between the ends of the two rods, and is concentric with them. When the test-sample is set horizontally, the lengthening-rods are either led through the side walls of the bath and provided with stuffing boxes as in Fig. 3 (Unwin) [21], or a ∩-shaped piece, which grasps the walls of the hot bath, is inserted between the sample and the tension-rod at each end of the latter (Martens [10], see Fig. 4, and Charpy [16]). The application of this piece to the test-sample end connected with the load-measuring appliance of the tensile-test machine has the advantage that the frictional resistance experienced in the stuffing-box is eliminated from the power measurement. In the case of a fixed bath the clear width between the flanges of this piece need

only be small; it will suffice, if it allows full play to the power-measuring appliance.

The proportion borne by the length of the bath, which is also equal to that of the tension-rods, to that of the test-sample must be as great as possible in order that the conduction of heat through the tension-rods may be kept as far apart from the test-sample as possible and the bar heated evenly throughout its length. With regard to uniformity of heating, the testing arrangements with horizontally-set sample are to be preferred to those in which the sample stands in the vertical position. In the latter case stirring arrangements, for the attainment of uniform temperature throughout the column of fluid, are indispensable. These, however, impede the measurement of the elongation during the test, and do not always effect their purpose. This is clearly seen from the circumstance that the sample breaks at its upper or at its lower end, according as the breaking-strength of the material decreases or increases with increases of temperature within the various temperatures of the bath that are present for the time being [11].

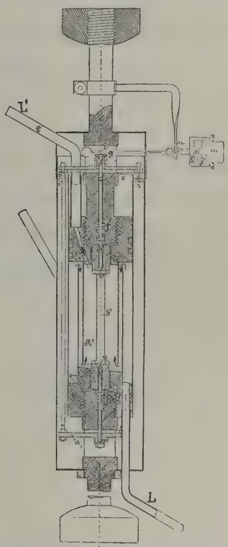


Fig. 5.
The Rudeloff Stove with Mirror Apparatus.

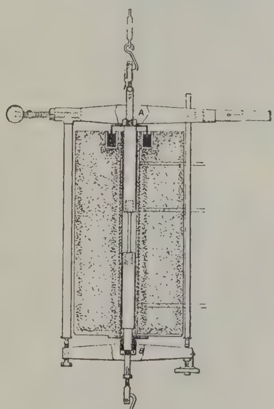


Fig. 6.
Electrically-Heated Stove (Nitrogen Bath) of Hopkinson and Rogers.

Air baths have the drawback that they cause oxidation of the test sample, which gradually makes its way from the surface into the interior. As is shown by Le Chatelier [26], this proceeds

with special rapidity in the case of impure copper obtained by smelting, but takes place also when this metal is obtained by electrolysis. The copper then becomes brittle and finally crumbles away[1]). Stribeck (29) looks on the thin superficial layer of oxidation as a good preservative, so long as it does not spring off and individual ingredients of the alloy do not evaporate, as in the case of brass after certain temperatures are reached. A further drawback to the air-bath is the incomplete conductivity of heat between the test sample and the surrounding air, which makes it necessary to measure the actual temperature of the piece tested instead of that of the bath.

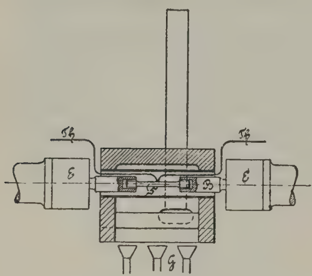


Fig. 7.
The Charpy Air-Bath.

For the prevention of oxidation in the air-bath I made use [14] of baths of steam (100⁰ C.), naphthaline vapour (200⁰ C.) and naphthylamine

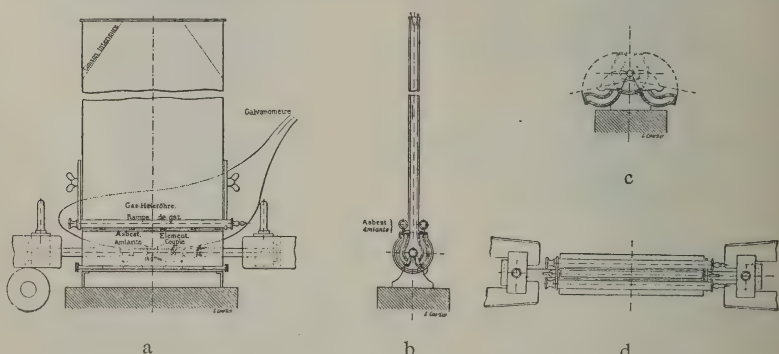


Fig. 8 a—d. The Le Chatelier Air-Bath.

vapour (300⁰ C.) in a special stove (Fig. 5). The vapours, which are produced in a copper vessel, enter the stove at L, take the course shown by the arrows between two pipes inserted the one in the other in telescope fashion, and then, after they have reached the sample, pass off through the gripping appliance and the pipe L′. Hopkinson and Rogers [35] made use of nitrogen baths in their stove (Fig. 6) with quicksilver seals

[1]) See also Heyn.

at the ends. For heating the air baths Charpy 18 and Le Chatelier [26] made use of gas jets (See Figs. 7 and 8), Stribeck [29] and Hopkinson & Rogers (35) of electric heating coils (See Figs. 5 and 9). The latter present the great advantage that by means of closer coiling at the ends of the stove (Stribeck), or by triparting of the coils and regulation of the current in the different parts (Hopkinson), the conduction of the heat through the tension-rods and grips can be better equalized and a more uniform heating of the test-sample throughout its length can be attained. Carpenter [19] envelopes the test-sample in a double cast-iron sleeve of considerable thickness and heats it from without with a Bunsen burner. The sleeve reaches beyond the measuring length of the sample by 25 mm at each end. The testing-temperature is read from a nitrogen thermometer, which passes through the sleeve. That errors in the determination of the temperature are entirely avoided by the circumstance that the tests are made after the thermometer readings have remained steady for the space of a few minutes, appears at the very least doubtful, especially in view of the fact that at the test the aperture between the sleeve and the sample increases with the elongation of the latter.

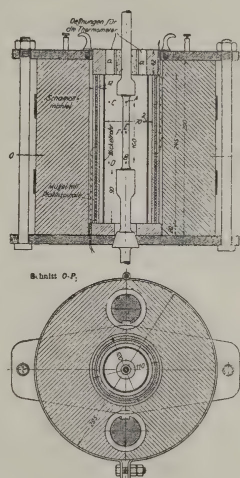


Fig. 9.
The Stribeck Electrically-Heated Bath.

For conducting ball-pressure tests in the hot bath, Kürth [38] has produced a very suitable method. The sample takes the form of a strip of 200 mm in length by 35 mm in breadth. All the points of pressure are arranged at its centre-line, and the same temperature being preserved throughout, several are set at considerable distances (40 to 50 mm) from one another, and then, between these, one each for the other temperatures. In this manner the influence of the want of uniformity of the material can easily be taken into account by the construction of curves with the observations for equal temperatures set off at abscissae equal to the distances apart of the pressure lines. The curves are for the most part of a regular kind and run parallel to one another, and

in the case of chemically pure materials lie parallel with the axis of the abscissae, their distance one from another corresponding with the differences in hardness at the testing temperatures employed. To enable the pressure to be exerted at the right place, the strip is made so that it can be shifted on its bed (lower pressure plate) along a graduated slide with a catch-pin in a direction parallel to the axis for the distance required, this taking place in the bath at constant temperature. The bath receptacle, a narrow iron box with double side walls stuffed between with infusorial earth and capable of being heated from below by several Bunsen burners, has the lower pressure-plate in the middle The steel ball is attached by means of thin perforated plates to the upper pressure-plate; it dips with the plate into the bath, but in order to admit of repeated examination it is so arranged that it can easily be raised. The annealing and the decrease of hardness of the ball thereby occasioned, as also the reduction of friction between ball and test-sample caused by the bath, proved in the case of the materials tested and at the temperatures in question (about 500^0 C.) to be devoid of influence.

As general result of the experiments made by Kürth, it may here be stated, that during their continuance the increase of hardness with additions of load for copper at 500^0 C. was the same as that at 0^0 C. in accordance with which at high temperature also no annealing effects on the hardness became, apparent provided such annealing of the samples was previously completely carried out.

For the determination of the elastic behaviour of the material and of the yield-point by the amount of the permanent set, the course taken by the elongation as the tension increases during the experiment must be noted. For this, the determination of the movements of the grips with reference to one another is not sufficient, and indeed reliable values can be obtained only when the measuring-instruments are applied directly to the sample. In this, great difficulties are experienced, owing to the circumstance that the measuring-instruments have to project from the bath or stove, so that their parts are subject to different heat effects. The first workable arrangements were created by Martens [11[, who applied to them his mirror apparatus, by which the elongation is translated into a rocking motion of a rhombic steel block connected with a mirror. The measurement is taken (see Fig. 1)

along two length-portions of the sample; that part of the total extending over the testing length (the thinner portion of the sample) must therefore be obtained by calculation. A slight inaccuracy here arises from the circumstance that the upper part of the measuring length, which protrudes from the stove, is not uniformly heated, so that the assumption underlying the calculation, that the same coefficient of elongation α as that for the lower more highly heated part may be applied to it, is not justified. A further source of error lies in the circumstance that variations of temperature cause alterations of length, which effect the measurements. This error is counteracted as far as possible by the practice of not beginning the test till a uniform condition of heat is attained in the sample and in the grips — showing itself in the circumstance that the weigh-lever stands steady under the initial load — and by taking care that no further alteration is made in the heating apparatus during the test.

In the tests conducted by me Martens mirror apparatus were also used; the transference of the elongation to the mirror-holder was, however, effected in a different manner. In the application of the stove (Fig. 5) the end-points o and u of the measuring-length lay in the axis of the short test-sample P, within the two sample heads, whence the rods S, a, t, and S' were led to the mirror-holder, being made to bear by means of springs f. The mirror-holder rested at h with one of its points against the upper end-surface of the rod S' and with a second point against the ring g, which was connected with the lower measuring-point. The movement of these two bearing points towards each other corresponded with the elongation of the test sample, and caused a tipping of the mirror m, held by the arm n.

In this arrangement, again, the measuring-length comprehends parts of the sample having different diameters, so that here, also, the true elongation has to be obtained by calculation. The length of the thicker part, however, is very small, and, above all, the whole range of measurement, as well as the measuring apparatus, lies within the stove, so that the observations are not influenced by the variations of temperature. Comparative tests [14[made at room-temperature with this apparatus and the ordinary Martens mirror-apparatus have proved that the differences in the results

of the two series were no greater than those in several tests made with apparatus of the old pattern. The manipulation of the apparatus, however, proved very difficult, and it was found that shocks easily caused a sliding of the supporting points. In my later tests [15, 20, 23] the Martens mirror-apparatus was accordingly again applied; only the measuring springs took the altered form observable in Fig. 10, and two pairs of springs, m and m_1, were placed against the sample, the mirror-holder s being inserted between them above.

By this the advantage is secured that alterations of the lengths of the springs due to fluctuations of temperature exercise hardly any influence on the measurements of elongations, because all the springs project by equal amounts from the stove, and are thus subject to the same variations.

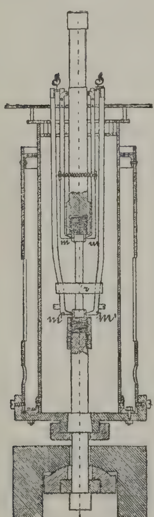


Fig. 10.
The Martens Fluid-Bath and the Rudeloff Mirror Apparatus.

In the horizontal arrangement of the test-sample and fluid baths the ordinary Martens mirror apparatus have done good service. The spindle of the mirror-holder must be made to protrude as far as possible through the lid of the bath, and below the mirror light discs must be provided to ward off the rising vapour.

Special attention is to be given to the determination of the temperature of the test-sample. In the case of a fluid bath it may suffice to determine the temperature of the latter, provided the beginning of the test is delayed till complete uniformity of temperature is attained, a condition of things which, as mentioned above, is readily recognised by the circumstance that the weigh-lever remains in equilibrium below the initial or zero load, while, by reason of the alterations of length produced by them, fluctuations of temperature cause a rising or falling of the lever. In the case of air-baths the heat of the sample is to be directly measured. Most suitable for this are thermo electric elements, which must be laid close against the sample and separated from the air-

bath by asbestos. The most accurate measurements will be attained, if a second sample be laid alongside the latter in the bath, its axis being bored out to take the thermo electric element.

The dimensions of the sample and the arrangement of the grips may exercise considerable influence on the result in so far as the uniform heating of the first-named within the measuring-length to a very considerable degree depends on them. That the length of the sample must for this purpose be considerably less than that of the bath, has been mentioned above. Martens (11) accordingly made use of samples of the greatest lengths possible, which were turned down to the desired test-section only within a comparatively short distance (see Fig. 1). On account of the large amount and high cost of manipulation of the material of construction attaching to this system, samples of the shortest possible length ($l = 100$ mm, see Fig. 5 and 10) were made use of in my tests (14, 15, 20, 23) the threaded ends of which were screwed into lengthening-rods. At a later date Bach (24, 25, 30, 31, 33, Fig. 2) and Stribeck (29, 32, Fig. 9) made use of similar rods. The accumulations of material at the two points of connection are altogether advantageous, since they at the same time serve as heat reservoirs and protect the test sample from the tendency to give off heat to the outside.

As we know, the speed of loading or of the application of the tensile test makes itself felt in the tests at room-temperature, in so far as, under circumstances in other respects identical, smaller strength-values and greater elongations are obtained as the speed diminishes. The falling-off of the strength as the speed of loading diminishes is also clearly apparent at higher temperatures, and especially when the sample has, at all events at testing-temperature, not been annealed before, but has by reason of previous treatment, somehow been subjected to hardening, because in that case the influence of the duration of a calcining heat on the annealing also plays a part. Thus, for instance, Le Chatelier (26) found, for hard-drawn copper wire of a strength of 50 kgs. per sq. mm at 250^0 C., the following values:

Duration	20 Sec.	10 Min.	30 Min.
Strength	34	24·7	18 kgs. per sq. mm.

On the other hand he found the following values for calcined copper samples: —

Temperature	200° C.			330° C.			400° C.			
Duration of test	45″	1′50″	10′	2′15″	10′	20′	56″	2′	5′30″	17′30″
Tensile strength in kgs. per sq. mm	20·4	18·6	17·9	15·7	15·2	14·7	10·6	9·7	8·2	7·8
Ultimate elongation per cent	39·0	35·0	36·0	37·9	34·4	31·1	21·0	16·2	12·9	11·4

Stribeck (29) found, in the case of copper, that the diminution of strength with increase of temperature at a rapid test did not begin till 300° C., while at a very slow test it began as early as at 200° C.

Very great sensitiveness to the rapidity of loading is possessed by zinc (see Martens [10]). Again, Kürth (38) found in connection with the ball-pressure test, that after several hours of uniform loading a state of equilibrium had still not been reached, while with most metals this showed itself after not more than from 5 to 10 minutes.

The ultimate elongation is, at high temperature, not subject to the influence of this rapidity to the same degree as in the case of room-temperature. As the above-mentioned experiments of Le Chatelier have already shown, the elongation of copper does not increase with reduction of speed, but diminishes. Stribeck comes to the same conclusion, and says that in case of long duration of the tests the samples break short off, while, at a rapid test under the same temperature, fracture was preceded by a considerable degree of contraction. Whether, and to what extent the influence of oxidation in the air-bath, mentioned in the beginning of this report, here played a part, may remain matter of opinion. The examples given may be taken as showing sufficiently, that, for the attainment of comparable results, a uniform rapidity of loading is necessary. To enable results of practical value to be obtained, it ought to be kept as low as possible, and the material for the samples should be annealed beforehand.

Test Results.

1. Wrought Steel.

The tests made so early as in 1837 by the Franklin Institute [2] showed that the tensile strength of wrought steel rose with increase of temperature. Knut Styffe [6] came to the same conclusion in 1863, and found that the ultimate elongation at the same time diminished. His experiments were extended to temperatures ranging up to not more than about 170° C. and in view of the imperfect nature of the testing arrangements adopted compared with those of the present day, their accuracy was so doubtful, that the results then observed are not given here. Huston [8] likewise found for

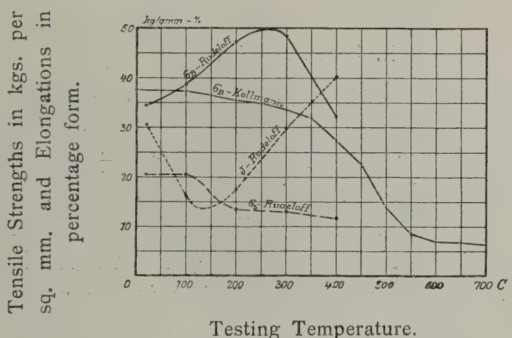


Fig. 11. Wrought Steel.
Tensile Strength σ_B, Yield Point σ_S and Elongation δ.

charcoal iron an increase of strength combined with a lessening of the diminution of sectional area up to 500° C. Kollmann [9], on the other hand, found no increase, but a continued diminution of strength (see Fig. 11). Up to 300° C. the latter was of only small amount (from 37.5 to 33.8 kgs. per sq. mm) — at the higher temperatures, however, up to 600° C., it was considerable. Although the Kollmann determinations of temperature by means of the calorimeter do not lead us to expect any high degree of accuracy, his observations, at variance with the older observations as they are, cannot without further question be put down to testing errors, especially in view of the circumstance that their results are of an exceedingly uniform character. My experiments [14] (see Fig. 11) confirm Styffe's observations, the highest tensile strength value

being obtained at about 260° C. (at a guess, 50 kgs. per sq. mm., as compared with 34 kgs. per sq. mm. at 20° C.), and at the higher temperatures, as in the Kollmann experiments, a considerable fall took place in the diminution of the strength. The yield-point fell considerably between 100 and 200° C.; before and after this point (up to 400° C.) it remained almost unaltered. The ultimate elongation fell between 20 and 130° C. from 30 per cent to 13½ per cent, and then, in contradistinction to what was observed in the Huston tests, rose again (fall in the diminution of sectional area) rapidly (up to 40 per cent at 400°). Carpenter's experiments [19] likewise showed the greatest strength at about 250° C. and the least elongation at about 130° C.

2. Soft Steel.

Tensile tests at different temperatures, carried out by Huston [8], Kollmann [9], Martens [11], Rudeloff [14], Charpy [16], Carpenter [19], Le Chatelier [62] and von Bach [31], are in existence. The experiments of Kollmann gave for Bessemer iron a constant fall in the tensile strength as the temperature increased, while all the rest agree in showing that the tensile strength at about 250° C. reaches a maximum that is far above that of room-temperature, and then with further access of heat, rapidly falls. According to the experiments of Martens and the author the increase in the tensile strength referred to is preceeded by a fall in the same, the minimum apparently being reached at about 50° C. Similar hehaviour of soft steel was established by Brinell [36] and by Kurth [38] in connection with ball-pressure tests. While, however, Brinell, whose observation-results, set off in the form of curves, showed complete agreement in general trend, obtained the first minimum value at about 200° C. and the maximum at 300—400° C., for acid as well as for basic material, the two points of contrary flexure of the curves of Kurth lie at 150—190° C. and at 250° C. respectively.

The yield-point of soft steel falls steadily with increase of temperature. With rising temperature the ultimate elongation likewise undergoes a considerable fall — according to Martens, for instance, in one case from 28·4 to 8·4 per cent — and thereupon a considerable rise. In general the minimum values lie at

about 150⁰ C., that is to say at lower temperatures than the maxima for the ultimate strength.

The initial assumption in regard to the elongation and increase of strength with rise in temperature explains the blue-shortness of the steel, which was pointed out by Valton so long ago as 1877 (Berg- und Hüttenmännische Zeitung 1877, Page 25) as the outcome of bending experiments.

3. Cast-Steel.

Fig. 12 shows the values obtained by me (23) and by Bach (30 and 31) for the tensile strength σ_B and the ultimate

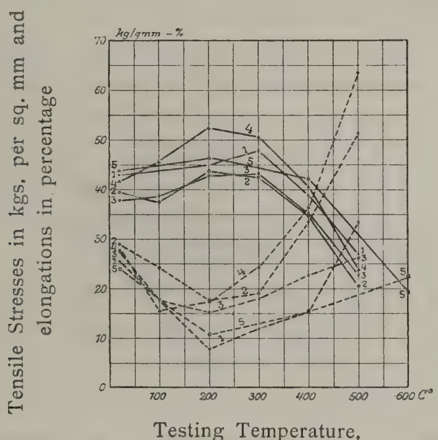


Fig. 12. Cast-Steel.
—— = Tensile Strength σ_B, --- = Ultimate Elongation δ.
According to Bach, Material 0 = 1, K = 2, M = 3, OE = 4, Rudeloff 5.

elongation δ of cast-steel. Bach gives the following particulars in regard to the composition of his 4 kinds of steel:

Kind	C	Mn	Cu	Si	S	P	As
O	0 193	0.322	0.096	0 187	0.087	0.081	0.056
K	0.165	0.726	0,121	0.498	0.038	0.019	0.041
M	0.200	0.819	0 273	0.112	0.048	0.053	0.073
OE	0.180	0.360	0.060	0.280	0.080	0.071	0.079

The general run of the curves is the same for all 5 kinds. The tensile strength at first increases with rise in temperature, attains its maximum value between 200 and 300° C., and then falls comparatively quickly. The ultimate elongation is influenced by the temperature in the opposite sense; it at first falls, and then rapidly rises, the minimum values being reached at about 200° C.

According to its magnitude, the influence of the heat fluctuates with the different kinds of steel, and especially the lines for the elongation diverge widely from one another at temperatures above 200° C. In this the influence of the rapidity of loading no doubt played a considerable part, but in other respects also the Bach experiments do not enable us to detect any regular influence exerted by the chemical composition of the material on its power of resistance to effects of temperature. It may, however, be pointed out, that the material OE, in the manufacture of which very particular attention was paid to the attainment of satisfactory behaviour at high temperatures, shows the greatest increase of strength and in general also the greatest ultimate elongation.

At the mean tensile-strength σ_B of 41 kgs. per sq. mm and ultimate elongation δ of 27% at room-temperature, the following approximate values may, with cast-steel, be assumed for the alteration of the strength-qualities at high temperatures.

Degree of Temperature C.		100	200	300	400
Percentage of Alterations from that at 20°	σ_B	+ 6	+ 12	+ 10	− 7
	δ	− 30	− 50	− 33	± 0

The contraction of area behaved similarly to the elongation, but its fall with rise of temperature was less considerable. The yield point fell steadily with the increase of temperature.

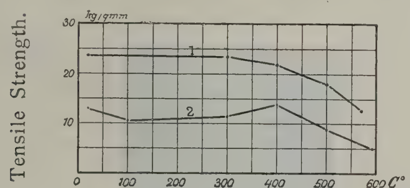
4. Cast-Iron.

Howard [12] found that up to 386° C. cast-iron lost but little of its strength. At higher temperatures the strength gradually diminished „but in such small degree, that it ultimately possessed

the same strength as soft steel". Previous to fracture, numerous cracks appeared.

My experiments [23] and those of Bach [25] (see Fig. 13) confirm the observation made by Howard, that the strength of cast-iron does not suffer an appreciable loss of strength till temperatures of 300 to 400° C. are reached. If the strength in room-temperature be set at 100, we obtain the following comparative values: —

Degree of Temperature C.		20	300	400	500	570
Comparative value according to	Bach	100	99	92	76	52
	Rudeloff	100	88	107	68	38



Testing Temperature.

Fig. 13. Cast-Iron.
Tensile Strength σ_B: 1 according to Bach, 2 according to Rudeloff.

In the above, the average composition of the material experimented with was: —

Material	Graphite	C combined	C total	Mn	Si	Cu	S	P
Bach	2·85	0·79	3·64	1·73	1·178	0·170	0·085	0·158
Rudeloff	—	—	3·56	0·93	2·650	—	0·054	0·517

The experiments of Kurth [38] showed that the ball-pressure hardness of the cast-iron subjected to test at first fell slowly as the temperature rose, then rose again slightly between 200° and 300° C. and finally fell very rapidly after the latter limit was passed. The experiments therefore show an approximate agreement with the tensile tests of the author (see Fig. 13).

5. Malleable Cast-Iron.

Experiments made by the author (23) with test-samples of $12 \times 6{,}5$ mm in section yielded the results given in Fig. 14,

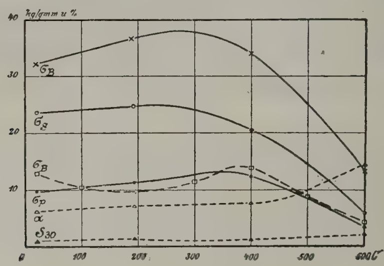


Fig. 14. Malleable Cast-Iron.

——— = Stresses, - - - = Elongations for Malleable Cast-Iron,
— — — = Ultimate Stress σ_B for Cast-Iron.

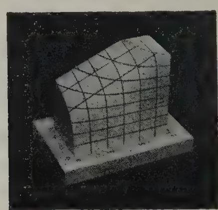


Fig. 15. Cast-Steel.

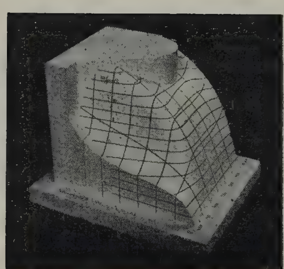


Fig. 16. Cast-Iron.

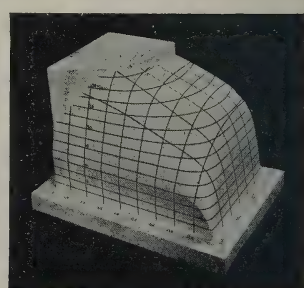


Fig. 17. Malleable Cast-Iron.

with the addition of the line for the tensile strength [23]. According to these, σ_P, σ_S, σ_B at first rise with the temperature; they reach their maxima at about 250—300^0 C. and then fall rapidly at still

greater heats. The values for σ_P at all temperatures agree approximately with the ultimate strength of cast-iron. The elongation α within σ_P increases slightly up to 400° C. and rapidly at higher temperatures. The ultimate elongation which is small in itself, is hardly affected by alterations in temperature.

Figures 15—17 are concrete illustrations of the test-results for cast-steel, cast-iron and malleable cast-iron. Fig. 15 shows clearly how the yield-point, which at room-temperature is sharply defined, becomes more and more indistinct at high temperatures, and falls till the curve at 600° C. finally takes a course similar to that for cast-iron (Fig. 16) at room-temperature. Between cast-iron (Fig. 16) and malleable cast-iron (Fig. 17) a marked difference appears, in that the strength of the former beyond 400° C. falls rapidly and that of the latter only gradually.

6. Copper.

Figs. 18 and 19 show the comparison between the tensile strengths σ_B and ultimate elongations δ obtained by extension-tests by myself [14 and 20], Unwin [21], Le Chatelier [26] and Stribeck [29]. It may be seen from Fig. 18 that in all the experiments σ_B steadily fell as the temperature rose. The great differences in the observation-values are due partly to the chemical composition, partly to the previous treatment of the material, and partly to differences in the rapidity of loading. It is due to the latter circumstance that Line No. 7 of 61° C. lies considerably lower than all the others; the corresponding observations differ from those of the other series in being obtained by tests of long duration. The experiments of Line No. 7 made at the lower temperatures, were conducted in the ordinary manner, and their results agree with those of Line 3b.

The influence of the previous treatment on the tensile strength in tests of ordinary duration appeared, according to the comparison of Lines 2a and 2b for hard-drawn material with Lines 2b and 3b for the same, but calcined material, in the well-known increase of strength by cold manipulation; beyond about 250° C. it gradually ceased as the temperature rose, and at 500° C. and beyond, it was no longer appreciable.

The influence of the chemical composition is clearly seen in Lines 2 and 3, and indeed it was the greater amount of tin, of

1·86%, which gave Material No. 2 the greater strength. Above 300° C. the difference recedes more and more, but is still observable at 600° C.

The differences in the ultimate elongation (Fig. 19, of the kinds of copper tested are much greater than those in the strength (Fig. 18). The influence of the inequality of the measuring-length shows itself as small compared with that of the previous treatment

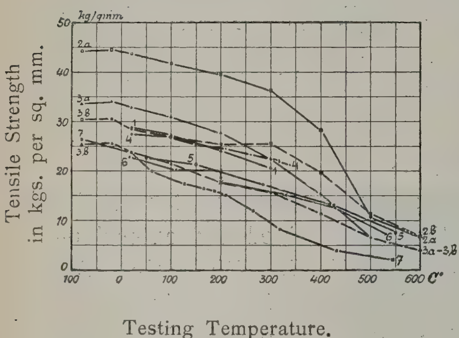


Fig. 18. Copper. Tensile Strength.

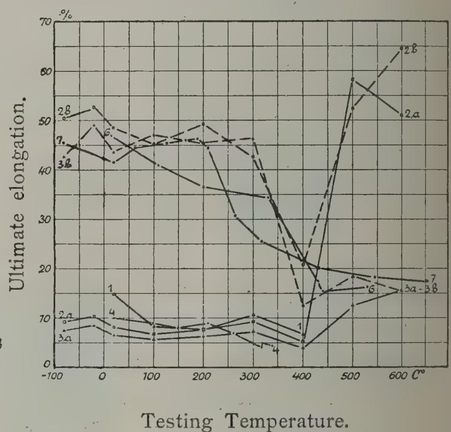


Fig. 19. Copper. Ultimate elongation.

1 Rudeloff 1893,
2 and 3 Do. 1898,
2a and 3a hard drawn,
2b and 3b calcined,
2a and 2b with 1·86 per cent of tin,
3a and 3b with traces of tin,
4 and 5 Unwin 1899,
6 Le Chatelier 1901,
7 Stribeck 1903. Very Slow increase of Load.

According to the comparison between 2a and 3a, hard-drawn with calcined material and to the good agreement between 3b and 7 the effect of the previous treatment appears so marked, that the conclusion may be drawn with tolerable certainty from the position of the lines (Fig. 19), that Line 7 also refers to calcined, and Lines 1 and 4 to mechanically hardened material.

The influence of heat shows itself in the calcined material (2b, 3b, and 7) up to 200° C. to be very small; then the elongation

falls rapidly with increase of temperature, till at 400—450° C. it appears to have attained its minimum value, and finally, with the exception of Material No. 2, does not alter much more up to 600° C. With the hard-drawn kinds of copper Nos. 2a and 3a, with which Nos. 1 and 4 are in fair agreement, the elongation in the first place at 100° C. shows a minimum, then increases with rising temperature till, beyond 300° C., it falls as in the case of calcined material, and then, rising again, it approaches the values found for the calcined material.

Very striking is the course of Line 2. In this material the elongation, after an initial decrease, increases again beyond 400° C. at an extremely rapid rate, and even exceeds the value for room-temperature. It appears not impossible that here also the effect of the percentage of tin contained by this material makes its appearance.

According to the experiments of Kürth [38] with copper, the ball-pressure hardness decreases, as in the case of pure silver in proportion to the increase of temperature. The values thus lie in a straight line. If they be determined from the diameters of the impressions produced by equal loads, the straight line for the annealed material, if produced, will apparently cut the axis of the abscissae at the melting temperature of the chemically pure metal in question. In the case of mechanically hardened (drawn) copper, the alterations of hardness for temperatures up to 250° C. likewise followed a straight line; at the higher temperatures annealing effects, depending upon the duration of the action of the temperature, made their appearance; the load points accordingly fell between the two straight lines for drawn and calcined copper respectively. Experiments, in which copper samples at certain given temperatures were calcined for different periods of time and after becoming cold again were submitted to the ball-pressure test, confirm the supposition that the calcining action begins in the case of copper at about 250° and then depends principally on the duration of the process; at 450 a duration of a few minutes will suffice for the complete removal of the hardening effect produced by previous mechanical treatment.

7. Copper, Zinc, and Zinc-Bronze.

In tables 1 and 2 the results of the various series of tests are put together, the bronzes being arranged according to their

Tensile Tests with Copper-Bronzes, Tin-Bronzes and Zinc-Bronzes.

Analyses.

Table I.

Running Number	Tests by	Copper	Tin	Zinc	Lead	Iron	Manganese	Phosphorus	Observations
1	Charpy	57·07	Trace	42·24	0·17	0·07	0·15	0·08	Cast hot
2		57·56	0·10	41·47	0·19	0·07	0·22	0·11	
3		58·99	0·31	40·27	0·17	0·06	0·30	0·09	
4		58·90	0·34	40·49	0·22	0·06	0·13	0·10	
5		58 97	0·05	40·40	0·18	0·07	0·18	0·08	Cast as cold as possible
6		56·20	0·11	42·95	0·13	0·05	0·33	0·07	
7		58·04	0·32	40·10	0·07	0·05	0·21	—	
8	Rudeloff	57·40	1·00	40·40	—	1·00	0·10	—	—
9	Bach	91·35	5·45	2·87	0·28	0·03	—	Trace	—
10		86·67	8·88	3·95	0·50	0·04	—	0·04	
11	Le Chatelier	—	10·00	3·00	—	—	—	—	—
12	Charpy	88·11	13·05	1·62	—	—	—	—	—

Properties at Various Temperatures.

Table II.

Numb. Nr. from Tab. I.	Nature	15–20	100	140	150	200	225	230	250	290	300	350	400	415	450	500
		Testing Temperatures in Centigrade Degrees														
1	Tensile strength in kg/cm²	39·5	—	—	30·8	26·8	23·5	—	21·4	—	—	—	—	—	—	—
2		36·4	—	—	30·0	27·8	24·8	—	20·5	—	—	—	—	—	—	—
3		38·6	34·7	—	30·8	27·8	24·0	—	21·4	—	—	—	—	—	—	—
4		38·7	—	—	—	28·7	24·6	—	21·8	—	—	—	—	—	—	—
5		35·9	35·4	—	34·1	30·8	28·1	—	26·7	—	—	—	—	—	—	—
6		38·5	41·4	—	37·4	29·4	27·4	—	25·4	—	—	—	—	—	—	—
7		44·0	37·4	—	36·4	34·0	32·1	—	28·7	—	—	—	—	—	—	—
8		45·2	43·3	—	—	37·0	—	—	28 7	18·5	—	9·5	4·9	—	—	—
9		24·0	24·2	—	—	22·5	—	—	—	—	13·0	—	6·3	—	—	4·4
10		24·9	24·8	—	—	23·8	—	—	20·3	—	16·1	11·6	11·1	—	8·3	6·9
11		15·9	—	16·6	—	—	—	14·4	13·2	—	12·0	11·0	—	6·4	—	—
12		22·7	20·7	—	20·1	18·1	17·4	—	16·0	—	—	—	—	—	—	—
1	Elongation δ per cent	25·0	—	—	30·0	42·0	37·3	—	37·5	—	—	—	—	—	—	—
2		26·0	—	—	41·0	48·4	52 0	—	52·8	—	—	—	—	—	—	—
3		42·0	45·0	—	43·0	52·4	46·0	—	41·5	—	—	—	—	—	—	—
4		32·3	—	—	—	40·0	31·0	—	26·5	—	—	—	—	—	—	—
5		15·0	27 3	—	34·7	47·5	46·5	—	55·0	—	—	—	—	—	—	—
6		8·4	13·6	—	29·0	44·0	40·8	—	65·2	—	—	—	—	—	—	—
7		16·2	11·7	—	19·7	40 0	40·2	—	45·2	—	—	—	—	—	—	—
8		35·9	39·6	—	—	38·9	—	—	73·7	65·7	—	74·5	67·8	—		—
9		36·3	35·4	—	—	34·7	—	—	—	—	11·5	—	0·0	—	—	0·0
10		17·4	20·1	—	—	17·9	—	—	12·1	—	6·8	2·0	1·5	—	0·5	0·3
11		5·7	—	7·1	—	—	—	3·9	4·2	—	2·0	1·4	—	1·4	—	—
12		4·5	6·3	—	13·1	5·8	4·0	—	3·3	—	—	—	—	—	—	—

increasing percentages of tin. As the temperature increases, the tensile strength diminishes in all the series, the ultimate elongation meanwhile increasing in case of the bronzes 1 to 8, which have about 40 per cent of zinc and 0 to 1 per cent of tin, and falling in that of bronzes 9 to 12.

The comparison is unreliable on account of the diversity of the testing methods employed, this referring more especially to the form of sample used, but in part also to the method of manufacture of the material, the casting temperature also exercising an influence. Thus a comparison between bronzes 1 to 4 and 5 to 7, which are of approximately the same composition, shows that the tensile strength of the hot-cast material 1 to 4 does not indeed differ much at about 20 from the cold-cast material, but falls at a quicker rate than the latter as the temperature increases, so that beyond 150° C. it is clearly beaten by it. Further at room-temperature the ultimate elongation of the hot-cast bronze is considerably greater than that of the cold-cast. As the temperature rises, this condition adjusts itself more and more, till beyond 500° C. the ultimate elongation of the cold-cast material is greater than that of the other.

The presence of tin in percentages of 0 to 1·0 per cent in hot-cast bronze containing about 40 per cent of zinc caused no considerable differences in the ultimate strength and elongation, but with the cold-cast material the ultimate elongation seems to diminish as the percentage of tin increases. The bronzes 9 to 12 with higher percentages (5 to 13 per cent) of tin showed considerably greater strength at room-temperature and in part also less ultimate elongation, than those with low percentage of tin just mentioned; at temperatures of more than 300° C., on the other hand, their strength was greater. For practical application, however, this is of no moment, since above 250° C. the strength of all the bronzes here under discussion is so small, that their use at such high temperatures is out of the question, and indeed, in case of material with from 10 to 13 per cent of tin, the more so that even at room-temperature small elongation became still further reduced with further access of heat.

8. Manganese Bronze.

The tests before us made on manganese bronze [14 and 15] such as is produced by the Isabellenhütte at Dillenburg by the

Heusler process, comprise rolled uncalcined bronzes with 3·2, 5·3, 7·3 and 9·4 per cent of manganese and cast bronze with 13·5 per cent of manganese at the temperatures between 20 and 400° C. The tests were made with the apparatus shown in Fig. 10 at 100 and 200° C. in paraffin, at 300° C. in a bath of melted tin and lead, and at 400° C. in a lead bath.

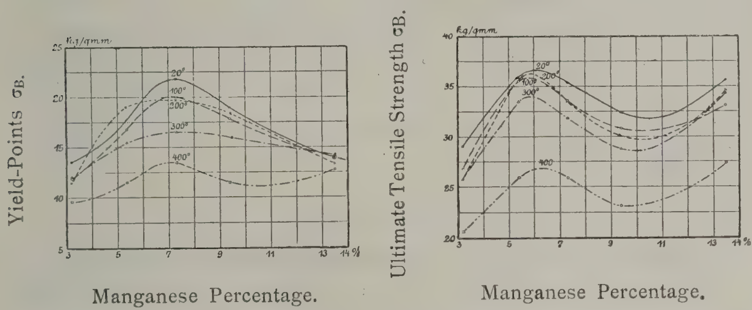


Fig. 20–21. Manganese-Bronze. Yield-Point and Ultimate Tensile Strength.

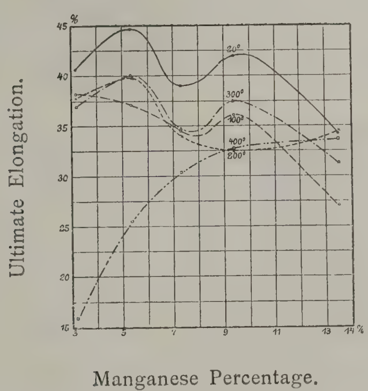


Fig. 22. Manganese-Bronze. Ultimate Elongation.

The test-results given in Figs. 20 to 22 by the aid of curves show that the yield-point δ_S (Fig. 20) and the ultimate tensile strength σ_B (Fig. 21) of the copper with increasing additions of manganese first increases and then diminishes again. The maximum values, the amounts of which can be taken directly from the figure lie for all temperatures almost throughout for σ_S at 7·3 per cent

of manganese and for σ_B at about 6 per cent of manganese. In the case of the cast 13·5 per cent bronze, σ_B reaches almost the same values as the 6 per cent material. The large ultimate elongation δ (Fig. 22) was obtained for the 5·3 per cent bronze; that for the bronze with 7·3 per cent of manganese was strikingly small.

As the temperature rises, the strength and the elongation diminish, but no influence, worthy of mention, in this direction showed itself till heat values of more than 200° C. were reached. As reaching the greatest strength and elongation, the bronze with from 5 to 6 per cent of manganese proved to be the most useful of all the kinds under observation for structural parts subject to tensile strains.

9. Delta Metal.

Investigations into the properties of delta metal made by the author [15] and by Unwin [21] respectively are forthcoming. According to the illustrations of the results of these given in Fig. 23, the Unwin metal, both in the rolled and in the cast condition, possessed greater strength and showed less elongation than mine. In the cases of both materials and under both conditions, the influence of higher temperatures showed a general

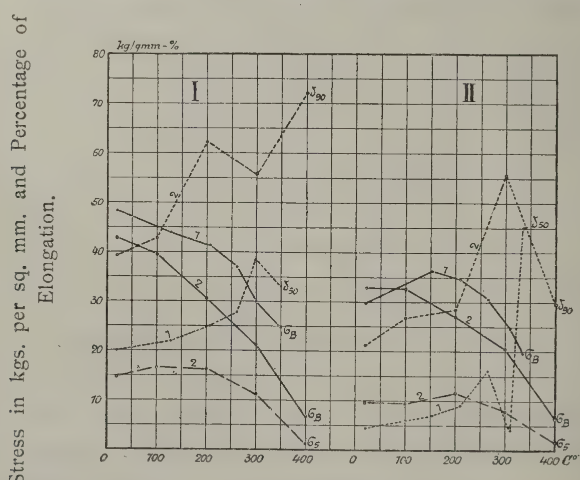
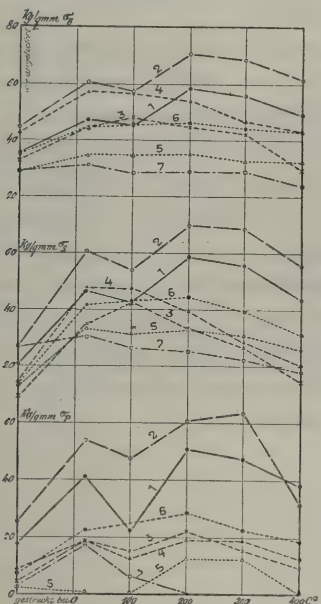


Fig. 23. Delta Metal: 1 according to Unwin, 2 according to Rudeloff. I as rolled, II as cast.

——— σ_B, ·········· δ, — — — σ_S.

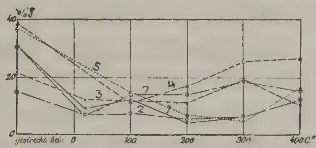
similarity. In the case of the cast material the tensile strength did not, up to 100^0 C., diminish to any considerable extent, and according to the Unwin tests it even increased; beyond this point, however, it underwent a steady decrease. The ultimate elongation increased. Beyond 200^0 C. irregularities showed themselves, and the question whether these were caused by side influences, or by differences in the rapidity of conducting the tests, or again by peculiarities of the materials under investigation, must be left unanswered.

Condition at Delivery.



Began to yield at.

Fig. 24.



Began to yield at.

Fig. 25.
Effect of Extension under different Degrees of Heat on the Ultimate Elongation.

Fig. 24.
Effect of Extension under different Degrees of Heat on the Stress Limits.

Material: 1. Wrought Steel,
2. Siemens-Martin Steel,
3. Cast } Delta Metal,
4. Rolled } Delta Metal,
5. 4 per cent } Manganese Bronze,
6. 15 per cent } Manganese Bronze,
7. Copper.

In my experiments, the stress at the yield-point remained almost unaltered up to 200^0 C., and then diminished steadily as the temperature rose.

The influence, for different temperatures, of the manipulation (previous extension) on the strength properties after re-cooling has taken place are shown for several metals (39) by Figs. 24 and 25.

The test-pieces are taken from the tensile-test samples made use of at the different temperatures, and are for the most part

cut from the parts of these that were most uniformly stretched. All the test-pieces are thus stretched in advance by the amounts of maximum elongation reached at the respective test-temperatures. Proposed additional tests with uniform previous extension for all the temperatures could not as yet be carried out. The run of the curves in Figs. 24 and 25 enables the alterations of the stress-limits σ_P, σ_S, and σ_B and the ultimate elongation S to be at once observed, so that it is not necessary to discuss these in detail. It may, however, be pointed out that the copper under investigation had been subjected to a certain degree of mechanical working even before the original test was made.

Le Chatelier (26) stretched swedish iron with 0·06 per cent C and soft steel with 0·163 per cent C at 190° C. and 220° C. by 3 and 3·5 per cent respectively and found the influence of the previous extension to be greater in the case of steel with a relatively high percentage of carbon, than in that of iron. According to Le Chatelier, the hardening is a result of "transformation..."; it requires time for its development, and by reason of this the influence of the extension at low temperatures decreases with increase of speed as a result of incomplete transformation. At temperatures above 250° C. he considers that the influence of the calcining acts in opposition to that of previous extension, and accordingly a rapid extension has greater effect here than a slow one.

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Report on the work done till now by the Subcommittee 1a for drawing up International Specifications for Iron and Steel.

The Subcommittee recognised it as convenient to come to an agreement on the most important points of the various specifications, viz.:

1. Material Manufacture and Test Regulations.
2. Properties of Material, as tensile-strength, elongation, etc.
3. Admissible Deviations from dimensions and weights.

The President of the Committee had therefore drawn up summaries, showing a comparison of the American, British and German specifications for structural iron, rails and fish-plates which should serve as the basis for the deliberation of the Subcommittee.

The Subcommittee held a meeting July 1st 1909 in the room of the Iron and Steel Institute in London. There were present: Messrs. Vehling, F. S. Robertson, F. W. Harbord and W. R. Webster.

Mr. Leslie S. Robertson, Secretary of the Engineering Standards Committee, attended in an advisary capacity and greatly assisted the deliberations of the Subcommittee through his familiarity with the specifications and the work under consideration.

Mr. G. C. Lloyd, Secretary of the Iron and Steel Institute, kindly agreed to act temporarily as Hon. Secretary for the purpose of taking the records of the business.

The members who were present expressed their thanks for the valuable work, done by the chairman Mr. Rieppel, by drawing up the summaries, and hoped that it might be possible to have the same published as part of the Committees report to be laid before the Congress in September, concerning the unification of the specifications for iron and steel.

The members of each country promised to check their own specifications carefully and to notify the chairman shortly of any alterations which may be recommended on behalf of the standardising authorities in their respective countries.

After considerable discussion on the part of the Subcommittee, it was however concluded that it would be inadvisable for the Commission at this time to recommend any material changes in

the standard specifications submitted, as the conditions of manufacture and rolling mill practice vary so much in the different countries, and it is thought that better material will be secured from any country under the conditions that have already been agreed upon by the recognised standardising authorities, consisting of engineers and manufacturers of the respective country, as given in their standard specifications.

The Subcommittee endeavoured to embody their views in the following resolutions and to suggest means of carrying on the work during the next three years with a view of ultimately arriving at one international specification for each class of material. In order to do this, however, the Subcommittee would require the assistance of the Committees in each country who have done such excellent work in the past, as shown by their specifications that they now have under consideration.

Finally the Subcommittee decided to ask the British Engineering Standards Committee to allow their Secretary, Mr. Leslie S. Robertson, to attend the Copenhagen Congress in an advisory capacity to the British delegates.

Resolutions embodying recommendations of the Subcommittee 1a on the question of International specifications for the Testing of Iron and Steel.

Resolved: 1. That the work of preparing the different specifications which have been submitted to us for consideration having been very thoroughly done in each country by Committees composed of engineers representing both consumers and manufacturers, the Sub-Committee Ia advises that the specifications of each country recommended by the Deutscher Verband für die Materialprüfungen der Technik, The American Society for Testing Materials, and the British Engineering Standards Committee be recommended for use for material manufactured in that country on export orders.

2. That the "comparative summaries" of the specifications of each country and the specifications themselves be printed in the Transactions of the Congress in French, German and English, and that in each case the requirements be given in the metric, American and British systems in order tho make an easy comparison of the specifications. In the event of the Council seeing fit to publish these specifications, the consent of the British

Standards Committee to publish the British specifications must be obtained and the Committee trusts that such consent will not be withheld.

3. That copies of these specifications be sent to the Deutscher Verband, the American Society for Testing Materials, and the British Standards Committee, and that, when at any future time these Associations have under consideration the revision of their own specifications, they be invited to compare them with the corresponding specifications submitted from other countries, and endeavour, wherever possible, to bring them into line with these.

4. That the present Sub-Committee (1 a) be continued, and that the Member of Council in each country be made the ex officio Chairman or Secretary of the respective meetings of that Sub-Committee.

5. That the Sub-Committee be instructed to hold a meeting once a year to consider what has been accomplished, and to present any new specifications that may be adopted by any ot the Associations for other classes of material than those now considered. These annual meetings to be held in either of the three countries most convenient to the Committee.

6. The Sub-Committee recommends the Commission to confer with the three Associations referred to above and keep them advised of the progress made, or suggestions offered, on modifications to bring the specifications more into line. That they also confer with the manufacturers direct, or through the Association, to induce them to roll trial orders of material under the conditions of the specifications of other countries, in order to find out how far these conditions can be introduced for export orders.

7. That a standard Drop Testing Machine for rails be adopted in each country, as has already been done in the United States, in order to make the tests comparative.

8. That a report be made at the next Congress, after that of 1909, on single international specifications for each class of material, even if in some cases they may be partially in the form of alternative specifications for the same class of material.

The President of Committee I, at the same time Chairman of the Subcommittee agreeing to these resolutions, begs to submit paragraphs 1, 3, 4, 6 and 7 of the same to the approval of the Congress.

In order to define more distinctly the lines for the future work of the Association in the domain of International specifications and to show the important economical advantages which could be brought about by them, the referee further desires to call the attention of the Congress to the following far-seeing suggestions of Mr. Wm. R. Webster, to whom the Committee is much obliged for his working out the proposals, which, after only slight alterations, have led to the above London resolutions.

Mr. Wm. R. Webster points out in a letter that the Sub-comittee has been successful in advancing the work owing to their policy to use only one specification from each country for any class of material and preferably the specifications of the branches of the International Association.

As to America a large committee, composed in equal parts of producers and consumers of steel, has succeeded after 12 years work in equalising the different specifications there existing and in establishing specifications which can be considered as good representative specifications of standard American practice.

"During this time all of those interested regarded the American Society for Testing Materials a Clearing House for Specifications.

What the International Association most needs is that the Sections, the National Societies in all other countries do similar work on specifications for their respective countries, then the International Association can likewise act as an International Clearing House for Specifications. If the work is carefully done by the committees in the several countries, it is not too much to expect that we will have a series of general international specifications, endorsed by the Association and recognised the world over by consumers and producers of steel and other metals. The most important features of these specifications will no doubt be very much the same, and will insure getting good uniform reliable material no matter where the orders are placed.

The minor requirements will no doubt vary, but the manufacturers in any country will only be asked to work under the requirements that they are perfectly familiar with.

Under the conditions as indicated above the purchasers of steel, rails on other material in any part of the world would

only have to consider prices and time of delivery, feeling that their interests would be fully protected by the international specifications wherever the orders were placed.

Il is hardly necessary to say that the adoption of a well defined policy on International specifications will be of the greatest benefit to the Association and the national Societies (Sections) of all countries; it is therefore to be hoped that the Congress agrees to the report of the subcommittee and to the plan of work suggested."

Sub-Committee Ia. **a**

International Specifications for Iron and Steel.

STRUCTURAL STEEL FOR BRIDGES AND GENERAL BUILDING CONSTRUCTION.

Comparative Summary of Specifications for Germany, Great Britain and the U. S. A. based on the following data:

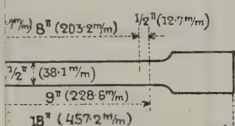
a) Drafts of uniform Specifications for Structural Steel (Einheitliche Vorschriften für Bauwerkeisen) of the "Deutsche Verband für die Materialprüfungen der Technik", approved 1906. No. 24. Booklet 2.

b) British Standard Specification for Structural Steel for Bridges and General Building Construction, published by the Engineering Standards Committee, London, June 1906. No. 15.

c) Standard Specifications for Structural Steel for Bridges, Standard Specifications for Structural Steel for Buildings, approved by the American Society for Testing Materials, 1909.

		U. S. A.	
			Structural Steel for Buildings
1	Material		Siemens-Martin or Bessemer.
2	Finish	ıjurious seams, flaws, cracks etc.	
3	Chemical An lysis and C ficate	ate re contents of:	P.
4	Chemical Co sition	est values in $^0/_0$	
5	Branding	with , ex- ɔther bove	Every finished piece of steel stamped with blow No. except that small pieces may be shipped in bundles with metal tag attached.
6	No. of test p	ding test from each melt of steel as rolled.	
7	Shape of tes specimens	g tests for plates, shapes and bars:	

Structural Steel	Rivet Steel
Bess 0.1 O. H. 0.06	0.06



with rned ngth ends	The standard shape of the test specimen for sheared plates shall be as shown by the sketch. For other material the test specimen may be the same as for sheared plates or it may be planed or turned parallel troughout its entire length and in all cases where possible, two opposite sides of the test specimen shall be the rolled surfaces.

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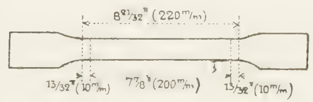
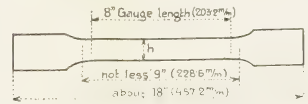
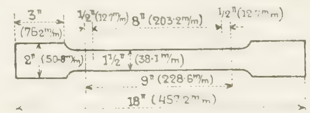
		Germany	Great Britain	U. S. A. — Structural Steel for Bridges	U. S. A. — Structural Steel for Buildings
1	Material	Siemens-Martin or Bessemer (Thomas).	**Siemens-Martin:** Plates, Rivets and Sectional material for bridges. Plates and Rivets for General Building Construction. **Siemens-Martin or Bessemer:** Sectional material for General Building Construction.	Siemens-Martin.	Siemens-Martin or Bessemer.
2	Finish	Smooth, free from cracks, blisters and defective edges.	Free from cracks, surface flaws, laminations, etc.	Smooth, free from injurious seams, flaws, cracks etc.	
3	Chemical Analysis and Certificate		Of each cast upon request of Purchaser.	Certificate re contents of: P. S. and Mn.	P.
4	Chemical Composition		Bridges %: P. 0.06; S. 0.06 Building Construction %: P. 0.06 Plates and Rivets, 0.07 Sect. Material; S. 0.06	Highest values in % Structural Steel: P. Basic 0.04, Acid 0.06; S. 0.05 Rivet Steel: 0.04; 0.04; 0.04	Structural Steel: Bess 0.1; O. H. 0.06 Rivet Steel: 0.06
5	Branding	Each piece to be marked, with No. of cast, in case of cast test being agreed upon.	All plates and sectional material marked in 2 places with maker's name or trade-mark, place where made, and No. or marks by which they can be traced to cast.	Every finished piece of steel marked with blow No. and name of manufacturer, except that rivet and lattice steel and other small parts may be bundled with above marks on attached metal tag.	Every finished piece of steel stamped with blow No. except that small pieces may be shipped in bundles with metal tag attached.
6	No. of test pieces	In case of a cast test being agreed upon: 3 pieces from each cast at most, however, 1 piece from every lot of 20 pieces or part thereof. In case of no cast test being agreed upon: 5 from each 100, at most, however, 1 piece from every 2 tons or part thereof.	One tensile test from every cast or 25 tons, whichever is least. One cold and one temper bend test from each plate, section or bar, as rolled.	At least 1 tensile test and 1 bending test from each melt of steel as rolled.	
7	Shape of test specimens	Area = $^1/_2$—$^3/_4$ sq. in. (300—500 mm²) for tensile strength. For rounds of less than dia: $^{25}/_{32}$" (20 mm): $l = 10 \times$ dia:  For bend tests: width $1^3/_{16}$—$1^{31}/_{32}$ (30—50 mm): Bars, rods, etc., in thickness according to use. Outer skin not to be damaged.	For plates and other structural material: for thickness: $> {^7/_8}$" (22·2 mm) — h = $1^1/_2$" (38·1 mm); $^3/_8$"—$^7/_8$" (9·5—22·2 mm) — h = 2" (50·8 mm); $< {^3/_8}$" (9·5 m) — h = $2^1/_2$" (63·5 mm)  For bars, rods and stays: Parallel for length of not less than 8 times dia: With enlarged ends: parallel for length of not less than 9 times reduced dia: Rivet Bars tested full size as rolled. Bend test pieces to be not less than $1^1/_2$ in. (38·1 mm) wide.	For tensile and bending tests for plates, shapes and bars:  Milled to form shown in sketch, or with both edges parallel; or they may be turned to a dia: of $^3/_4$" (19·1 mm) for a length of at least 9" (228·6 mm), with enlarged ends Rivet rounds tested as rolled. Special regulations for pins and rollers.	The standard shape of the test specimen for sheared plates shall be as shown by the sketch. For other material the test specimen may be the same as for sheared plates or it may be planed or turned parallel troughout its entire length and in all cases where possible, two opposite sides of the test specimen shall be the rolled surfaces.

Specifications for Structural Steel.

		Germany	Great Britain	U. S. A. — Structural Steel for Bridges	U. S. A. — Structural Steel for Buildings
8.	Test pieces	Cold, sheared edges, etc., removed by milling, planing, etc. Test piece to be annealed only when material from which it is taken is to be annealed.	Test pieces to be cut lengthwise or crosswise from plates, and lengthwise from Sect. Material and Bars. When material is annealed or otherwise treated, test pieces to be similarly treated. Straightening to be done cold. Sheared edges to be removed by milling, planing, etc.	When material is annealed or otherwise similarly treated, test pieces to be similarly treated.	
9.	Physical Tests, Properties:	see below	see below	see below	see below

9. Physical Tests, Properties:

Germany

Only for a thickness of $^{9}/_{32}''$—$1^{3}/_{32}''$ (7 to 28 mm).
[For other thicknesses as to be agreed upon.]

A. Tensile Tests:

	Tensile Strength lbs./sq. in.	Elongation %
Lengthwise	52.625—62.581 (37—44 kg/mm²)	$\geqq$ 20
Crosswise	51.203—64.004 (36—45 kg/mm²)	$\geqq$ 17
Rivets and Bolts	51.203—59.737 (36—42 kg/mm²)	$\geqq$ 22

B. Other Tests:

1. Plate, section or bar:

a) Bend tests:

	Test piece lengthwise	Test piece crosswice
Heating	light red hot.	light red hot.
Quenching	Water 28° C.	Water 28° C.
Dia: of loops	Single thickness	Double thickness
Fractures	Not permissible	Surface fractures permissible

b) Red hot breaking tests:

Got off by forging	Condition	Punch.	Fracture
Area: $1^{9}/_{16} \times {}^{1}/_{4}''$ (40 × 6 mm)	red hot.	$l = 3^{5}/_{32}''$ (80 mm) $d_1 = {}^{25}/_{32}''$ (20 mm) $d_2 = 1^{3}/_{16}''$ (30 mm)	Not permissible

Great Britain

	Tensile Strength lbs./sq. in	Minimum Elongation %
Plates and Sectional Material	62.720—71.680 (44·1—50·5 kg/mm²)	20

For material under $^{5}/_{16}''$ (7·9 mm) thick, bend tests only are required.

	Tensile Strength lbs./sq. in	Minimum Elongation %
Rivet Bars .	58.240—67.200 (41·0—47·3 kg/mm²)	25

Bend test unnecessary for rivet-bars.
Manufactured rivets: cold bend test: The shank shall be bent 180° until 2 parts of shank touch, with-out fracture on outside of bend.
Rivet head will be flattened, white hot, until its dia: is $2^{1}/_{2}$ times that of the shank, without cracking at edges.

U. S. A.

Structural Steel for Bridges

	Tensile Strength lbs./sq. in.	Elongation l	Elongation $\frac{1,500.000}{\text{Tensile Strength}}$ %
Structural Steel	60.000 (42·2 kg/mm²)	8" (203·2)	$\geqq$ 23
Rivet Steel	50.000 (35·2 kg/mm²)	8" (203·2)	$\geqq$ 27

Structural Steel for Buildings

	Tensile Strength lbs./sq. in.	Elongation l	Elongation $\frac{1,400.000}{\text{Tensile Strength}}$ %
Structural Steel	55.000 to 65.000 (38·7—45·7 kg/mm²)	8" (203·2)	$\geqq$ 23
Rivet Steel	48.000 to 58.000 (33·7—40·8 kg/mm²)	8" (203·2)	$\geqq$ 24

Character of fracture: Silky.

Elongation: For material less than $^{5}/_{16}''$ (7·9 mm) and more than $^{3}/_{4}''$ (19·1 mm) in thickness, following modifications allowed:
a) for each $^{1}/_{16}''$ (1·6 mm) in thickness below $^{5}/_{16}''$ (7·9 mm), a deduction of $2^{1}/_{2}$%.
b) for each $^{1}/_{16}''$ (1·6 mm) in thikness above $^{3}/_{4}''$ (19·1 mm), a deduction of 1%.

Buildings: Special regulations for pins.

Bend tests: by pressure or blows:

Bridges:

Plates, shapes and bars up to 1" (25·4 mm) thick: cold bend, without fracture, to 180°

Eye-bars and other steel 1" (25·4 mm) thick and over, tested as rolled.

Cold bend.	Dia of loop	
180°	double thickness	without fracture on outside of bend

Angles under hammer:
$^{1}/_{2}''$ (12·7 mm) and less thick bend shut } cold without fracture
$^{3}/_{4}''$ (19·1 mm) and less thick open flat } cold without fracture
To be made only when required by inspector.

Buildings:

Medium steel $^{3}/_{4}''$ (19·1 mm) and less thick, test specimen shall be of same thickness as of material from which it is cut, but for material thicker than $^{3}/_{4}''$ (19·1 mm), testpiece may be $^{1}/_{2}''$ (12·7 mm) thick. Width for both $1^{1}/_{2}''$ (38·1 mm).
Test: Medium steel shall bend cold 180° around a dia equal to thickness of specimen tested, without fracture on outside bend.

U. S. A.	
Structural Steel for Bridges	Structural Steel for Buildings

When material is annealed or otherwise similarly treated, test pieces to be similarly treated.

	Tensile Strength lbs./sq. in.	Elongation	
		l	1,500.000 / Tensile Strength %
Structural Steel	60.000 (42·2 kg/mm²)	8" (203·2)	$\geqq$ 23
Rivet Steel	50.000 (35·2 kg/mm²)	8" (203·2)	$\geqq$ 27

	Tensile Strength lbs./sq. in.	Elongation	
		l	1,400.000 / Tensile Strength %
Structural Steel	55.000 to 65.000 (38·7—45·7 kg/mm²)	8" (203·2)	$\geqq$ 23
Rivet Steel	48.000 to 58.000 (33·7—40·8 kg/mm²)	8" (203·2)	$\geqq$ 24

Character of fracture: Silky.

Elongation: For material less than $^5/_{16}$" (7·9 mm) and more than $^3/_4$" (19·1 mm) in thickness, following modifications allowed:

a) for each $^1/_{16}$" (1 6 mm) in thickness below $^5/_{16}$" (7·9 mm), a deduction of $2^1/_2$%,
b) for each $^1/_{16}$" (1·6 mm) in thikness above $^3/_4$" (19·1 mm), a deduction of 1%.

Special regulations for pins.

Bend tests: by pressure or blows:

Structural Steel for Bridges

Plates, shapes and bars up to 1" (25·4 mm) thick: cold bend, without fracture, to 180°

Eye-bars and other steel 1" (25·4 mm) thick and over, tested as rolled.

Cold bend.	Dia of loop	
180°	double thickness	without fracture on outside of bend

Angles under hammer:

$^1/_2$" (12·7 mm) and less thick bend shut	cold without fracture
$^3/_4$" (19·1 mm) and less thick open flat	cold without fracture

To be made only when required by inspector.

Structural Steel for Buildings

Medium steel $^3/_4$" (19·1 mm) and less thick, test specimen shall be of same thickness as of material from which it is cut, but for material thicker than $^3/_4$" (19·1 mm), test piece may be $^1/_2$" (12·7 mm) thick. Width for both $1^1/_2$" (38·1 mm).
Test: Medium steel shall bend cold 180° around a dia equal to thickness of specimen tested, without fracture on outside bend.

STEEL RAILS, etc.

Comparative Summary of Specifications for Germany, Great Britain and U. S. A., based on the following data:

a) Standard Specifications for Steel Rails (Einheitliche Vorschriften für Oberbaueisen) of the "Deutsche Verband für Materialprüfungen der Technik", adopted 1904. No. 23, Booklet 1

b) British Standard Specification for Flat Bottom Railway Rails, published by the Engineering Standards Committee, London, No. 11; Revised July 1909; British Standard Specification for Bull Head Railway Rails, Revised July 1909, No. 9; British Standard Specification for Tramway Rails and Fish Plates, No. 2, Revised 1909.

c) Standard Specifications for Steel Rails and Fish Plates of the American Society for Testing Materials adopted 1909.

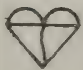
		U. S. A.	
		Rails	O. H. Rails
1	Material:	Bessemer Steel	Open Hearth Steel
2	Process of Manufacture:	Specified in Contract	
3	Finish:	Straight in line and surface, smooth on head sawed square at ends, no burrs and the ends made clean Not to vary throughout their entire length 5" (127 mm) from a straight line in any direction when delivered to the cold straightening presses	
4	Chemical Analysis:	Daily carbon determinations, for each blow and a complete analysis every 24 hours, representing average of other elements in steel, for each day and night turn	Determinations for each heat of all the elements specified
5	Chemical Composition: per cent		
	Carbon	0·35 - 0·55, 0·45 - 0·55	0·46 - 0·59, 0·62 - 0·75
	Phosphorous	0·1 not to exceed	0·04 not to exceed
	Silicon	0·2 " " "	0·20 " " "
	Manganese	0·7 — 1·00 0·84 — 1·14	0·60 — 0·90
	Sulphur	—	—
6	Section:	According to template furnished by Purchaser	

Specifications for Structual Steel.

		Germany	Great Britain	U. S. A.	
				Structural Steel for Bridges	Structural Steel for Buildings
9	Physical Tests continued	**2. Rivet and bolt material:** a) Bend Tests: Section: bars, rods, etc. Heating: light red hot. Quenching: Water with 28° C. (80° F.) Dia of loop: half thickness. Fracture: not permissible. b) Jumping Tests: length before jumping = 2 × dia. heating: as by rivetting. length after jumping = $^{2}/_{3}$ × dia.	Bend tests, cold and hot: When hot: Heating: blood red. Quenching: 28° C. (80° F.) Bending: 180°. Test pieces to withstand, without fracture, being doubled over until internal radius not greater than $1^{1}/_{2}$ times thickness of test piece, and the sides are parallel.	**Rivet Steel:** Dia. of loop: flat Break: gradual. Appearance: fine, silky, uniform fracture.	**Bend tests:** Bend cold 180° flat without fracture on outside of bent portion.
10	Rejection	For each test that fails, 2 further tests to be made from corresponding material, but should either of latter tests fail, material can be rejected. Should test piece break outside of the middle third of gauged length, another test to be made, if elongation insufficient.	Should test pieces first selected not fulfil requirements, 2 further tests may be made, but should either fail, material from which test pieces were cut shall be rejected. Further tests to be made before material from same cast is accepted. Should a tensile test piece break outside middle half of its gauge length, test may be discarded and another test made from same material.	If the ultimate strength varies more than 4000 lbs/sq. in. (2·8 kg/mm²) from that desired, a retest to be made which, to be acceptable, shall be within 5,000 lbs. (3·5 kg/mm²) of desired ultimate. Check analysis shall be made from finished material, if called for by purchaser; excess of 25% allowed.	Should test piece break outside of the middle third of gauged length, another test piece substituted therefore.
11	Permissible Variations	—	± $2^{1}/_{2}$% calculated weight.	With regard to permissible variations from specified weight and dimensions, there exist special regulations, for plates. For all other steel parts, the variation in cross section and weight of the single pieces may amount to $2^{1}/_{2}$% at the most.	

		Germany		Great Britain			U. S. A.	
		Rails and Tongue Rails	Tramway Rails	Flat Bottom Railway Rails	Bull Head Railway Rails	Tramway Rails	Rails	O. H. Rails
7	Branding:	Each rail to have manufacturers mark and year either when manufactured or when put to use in raised letters, also number of blow. All on web.		 Brand (see sketch) rolled on web „B. S.“ Number. Process of manufacture: name, initials or other recognised mark and month and year of manufacture rolled in $^{3}/_{4}''$ (19·0 mm) letters and the number of the cast or blow stamped in $^{1}/_{2}''$ (12·7 mm) block figures on end of each rail.		 Same, without mention being made of month	Name of maker, weight of rail and month and year of manufacture rolled in raised letters on the web and number of melt stamped on each rail.	Name of maker, weight of rail and month and year of manufacture rolled in raised letters on the web and number of blow and the letters O. H. stamped on each rail.
							Rails 70 lbs. per yard (34·7 kg/m) and over to have a letter stamped on side of web to indicate the portion of the ingot from which the rail was rolled.	
8	Impact Test: Drop	The rails have to stand the following tests: For rails weighing from $47^{4}/_{5}$ lbs/yd (23·8 m/kg) and over 10·850 ft/lbs (1500 m/kg) For rails weighing from $40^{1}/_{4}$ lbs/yd (20 m/kg) and down to $47^{4}/_{5}$ lbs/yd (23·8 m/kg) 7·233 ft/lbs (1000 m/kg) For rails weighing from $32^{1}/_{4}$ lbs/yd (16 m/kg) down to $40^{1}/_{4}$ lbs/yd (20 m/kg) 5·424 ft/lbs (750 m/kg)	The first blow 10.850 ft/lbs (1500 m/kg); the others 8680 ft/lbs (1200 m/kg)	8—30 ft. (2·44–9·14 m) In 17 stages for rails of 20—100 lbs/yard (9·9–49·5 kg/m)	5–7 ft. (1·52–2·12 m) 1st blow, 10–20 ft. (3·05–6·10 m) 2nd blow In 9 stages for rails of 60--100 lbs/yard (30-50 kg/m)	15 ft. (4·57 m) for rails less than 100 lbs/yard (49·5 kg/m) 18 ft. (5·48 m) for rails of and exceeding 100 lbs/yard (49·5 kg/m)	15—18 ft. (4·57—5·48 m)	In 5 stages for rails of 50—100 lbs/yard (24·8—99·5 kg/m)
	Weight of Tup			560-2240 lbs (254–1016 kg)	2240 lbs (1016 kg)	at least 2240 lbs. (1016 kg)	2000 lbs. (906 kg)	
							Anvil Block of 20000 lbs. (9060 kg) at least in standardized drop testing machine in general use to be described.	
	Length of test piece	4 ft. $3^{3}/_{16}$ in. (1·3 m)		5 ft. (1·52 m)	5 ft. (1·52 m)	5 ft. (1·52 m)	4—6 ft. (1·22—1·83 m)	
	Centres of bearings	3 ft. 3 in (1 m)		For 20—65 lbs/y. (9·9—32 kg/m) 3 ft. (0·9 m) For 70 to 100 lbs/y. (34·7-49·5 kg/m) $3^{1}/_{2}$ ft. (1·07 m)	3 ft. 6 in. (1·07 m)	3 ft. 6 in. (1·07 m)	3 ft. (0·91 m)	
	Number of blows	Until required deflection		1 blow	2 blows	1 blow	1 blow	
	Required deflection	At least $3^{15}/_{16}$ in. (100 mm) for section of heigh $5^{5}/_{16}$ in. (134 mm) and at least $5^{1}/_{8}$ in. (130 mm) for tongue rails. For other sections including tongue rails vice versa proportionately to the heights of sections.	At least $2^{3}/_{8}$ in. (60 mm) with sections up to heigh of $5^{15}/_{16}$ in. (150 mm): beyond that at least $1^{31}/_{32}$ in. (50 mm)	—	From $1''$ – $1^{5}/_{16}''$ (25·4–33·3 mm) to $^{7}/_{8}''$ – $1^{5}/_{16}''$ (22·2–33·3 mm) 1st blow: according to weight of section; From $3''$ – $3^{3}/_{4}''$ (76·2–95·2 mm) to $3''$ – $4^{1}/_{4}''$ (76·2–108·0 mm) 2nd blow: ditto	— —	— —	
	Number of Tests	1 Test for each lot of 200 rails and portion thereof.		1 test from each cast, in addition one finished rail from every 200 offered.	1 test from each cast	1 test from each 80 rails	1 test from every cast	

Rails.

ritain		U. S. A.	
Railway ls	Tramway Rails	Rails	O. H. Rails
on web manufac- ecognised nufacture e number (12·7 mm) rail.	 Same, without mention being made of month	Name of maker, weight of rail and month and year of manufacture rolled in raised letters on the web and number of melt stamped on each rail.	Name of maker, weight of rail and month and year of manufacture rolled in raised letters on the web and number of blow and the letters O. H. stamped on each rail.
		Rails 70 lbs. per yard (34·7 kg/m) and over to have a letter stamped on side of web to indicate the portion of the ingot from which the rail was rolled.	
n 9 stages or rails of 60--100 lbs/yard 30-50 kg/m)	15 ft. (4·57 m) for rails less than 100 lbs/yard (49·5 kg/m) 18 ft. (5·48 m) for rails of and exceeding 100 lbs/yard (49·5 kg/m)	15—18 ft. (4·57—5·48 m)	In 5 stages for rails of 50—100 lbs/yard (24·8—99·5 kg/m)
		2000 lbs. (906 kg)	
	at least 2240 lbs. (1016 kg)	Anvil Block of 20000 lbs. (9060 kg) at least in standardized drop testing machine in general use to be described.	
52 m)	5 ft. (1·52 m)	4—6 ft. (1·22—1·83 m)	
(1·07 m)	3 ft. 6 in. (1·07 m)	3 ft. (0·91 m)	
ws	1 blow	1 blow	
1st blow: according to weight of section	—	—	
2nd blow: ditto	—	—	
each cast	1 test from each 80 rails	1 test from every cast	

		U. S. A.		B
		Rails	O. H. Rails	lead Rai
9	Tensile Tes			len 3·71 45
	Dimensions oft piece			d le orte
	Tensile strengt	not called for		
	Elongation			
	No. of tests			
				in.
10	Rejection.	If any rail breaks under drop test, 2 additional tests will be made from same cast and if either of latter tests fail, all rails of such blow will be rejected		
				g
				p

Specifications for Steel Rails.

		Germany		Great Britain			U. S. A.	
		Rails and Tongue Rails	Tramway Rails	Flat Bottom Railway Rails	Bull Head Railway Rails	Tramway Rails	Rails	O. H. Rails
1	Material:	Ingot Steel		Steel			Bessemer Steel	Open Hearth Steel
2	Process of Manufacture:	Optional to be specified, however, in tender.		Optional the purchaser, however, to approve.			Specified in Contract	
3	Finish:	No cracks, fuse holes, injurious seams burrs or defects of every kind. Square at ends.	—	Uniform section throughout true to templates, perfectly sound and straight and free from splits, cracks, burrs and defects of any kind.		Uniform section throughout accurately rolled to conform to template, perfectly sound and free from twists, blisters, flaws, fins and other defects	Straight in line and surface, smooth on head sawed square at ends, no burrs and the ends made clean Not to vary throughout their entire length 5" (127 mm) from a straight line in any direction when delivered to the cold straightening presses	
4	Chemical Analysis:	Not required.		Carbon and phosphorous determinations of each cast. An analysis representing average of other elements in steel, to be given for each rolling up to 200 tons each. When rolling exceeds 200 tons an additional complete analysis to be made for each 200 tons or part thereof.	Carbon determinations of each cast. An analysis, representing average of other elements in steel, to be given for each rolling up to 200 tons each. When rolling exceeds 200 tons an additional complete analysis to be made for each 200 tons or part thereof.	Carbon determinations of each cast. An analysis, representing average of other elements in steel to be given for each rolling up to 100 tons each. When rolling exceeds 100 tons, an additional complete analysis to be made for each 100 tons or part thereof.	Daily carbon determinations, for each blow and a complete analysis every 24 hours, representing average of other elements in steel, for each day and night turn	Determinations for each heat of all the elements specified
5	Chemical Composition: per cent							
	Carbon	—	—	0·35 0·5	0·35 – 0·5	0·4—0·55	0·35 - 0·55, 0·45 - 0·55	0·46 - 0·59, 0·62 - 0·75
	Phosphorous	—	—	0·07 not to exceed	0·075 not to exceed	0·08 not to exceed	0·1 not to exceed	0·04 not to exceed
	Silicon	—	—	0·1 " " "	0·1 " " "	0·1 " " "	0·2 " " "	0·20 " " "
	Manganese	—	—	0·7—1·0	0·7—1·0	0·7—1·0	0·7 — 1·00 0·84 — 1·14	0·60 — 0·90
	Sulphur	—	—	0·07 not to exceed.	0·08 not to exceed.	0·08 not to exceed.	—	—
6	Section:	According to template furnished by Purchaser.		Each section to be accurately rolled to its respective template. 2 Sets of templates (internal and external) supplied by Manufacturer upon request of Purchaser.			According to template furnished by Purchaser	

		Germany		Great Britain			U. S. A.	
		Rails and Tongue Rails	Tramway Rails	Flat Bottom Railway Rails	Bull Head Railway Rails	Tramway Rails	Rails	O. H. Rails
11	Permissible Variations:							
	a) Dimensions in length	Up to $29^1/_2$ ft. (9 m) $+{}^1/_{12}$ in. (2 mm) Above to $29^1/_2$ ft. (9 m) $\pm{}^1/_8$ in. (3 mm) No variation in the case of tongue rails.	Up to 39 ft. 4 in. (12 m) $+{}^1/_8$ in. (3 mm)		Normal length 9·144, 10·973, 13·716 or 18·288 m (30, 36, 45 or 60 ft.)	Normal length 10·668, 13·716 or 18·288 m (35, 45 or 60 ft.)	Normal length: 30 and 33 ft. (9·144 and 10·058 m) $10^0/_0$ of order will be accepted in length varying by even feet to 24 feet (7·312m).	
				$\pm{}^3/_{16}$ in. (4·8 mm) specified length		$2^1/_2$—$5^0/_0$ shorter as specified	$\pm{}^1/_4$ in. (6·35 mm) specified length.	
				$7^1/_2{}^0/_0$ of contract may be shorter than specified		$\pm{}^1/_4$ in. (6·3 mm) from the lengths specified		
		$5^0/_0$ of contract may be shorter than specified						
	In straightness	Warped rails not accepted	Up to $^1/_8$ in. (3 mm) for $29^1/_2$ ft. (9 m) vertically and horizont. Those warped rails which are more than $\pm{}^1/_{18}$ in. (±1.5 mm) from the straight will not be accepted.				Square at ends not over $^1/_{32}$ in. (0·8 mm) variation. Must be straight in line and surface.	
	In position and size of holes	$\pm{}^1/_{25}$ in. (1 mm)	$\pm{}^1/_{25}$ in. (1 mm)	$\pm{}^1/_{32}$ in. (0·8 mm)	$\pm{}^1/_{32}$ in. (0·8 mm)	For Fishbolts $^1/_{16}$ in. (1·6 mm)	Must accurately conform to drawing.	
	In width of head	$\pm{}^1/_{50}$ in. (0.5 mm)	$\pm{}^1/_{25}$ in. (1 mm)				$^1/_{16}$ in. (1·6 mm)	
	In thickness of web	$\pm{}^1/_{50}$ in. (0.5 mm)	$\pm{}^1/_{25}$ in. (1 mm)					
	In width of bottom	$\pm{}^1/_{25}$ in. (1 mm)	$\pm{}^1/_{12}$ in. (2 mm)				$^1/_{16}$ in. (1·6 mm)	
	In heigth	$\pm{}^1/_{50}$ in. (0.5 mm)	$\pm{}^1/_{25}$ in. (1 mm)			$\pm{}^1/_{32}$ in. (0·8 mm). Distance between Fishing angles $\pm{}^1/_{64}$ in. (0·4 mm)	$-{}^1/_{64}$ in. to $+{}^1/_{32}$ in. (0·4 to + 0·8 mm)	
	b) Weight	$+3^0/_0$ to $-2^0/_0$	$+4^0/_0$ to $-3^0/_0$	$\pm{}^1/_2{}^0/_0$ calculated weight		max. 1 lb per yard (0·5 kg/m)	$\pm{}^1/_2{}^0/_0$ accepted and paid for according to actual weight.	
		Additional weight up to $1^0/_0$ will be paid for; otherwise the actual weight. Normal weight being the actual weight of 50 faultlessly rolled rails.	Additional weight up to $1^0/_0$ will be paid for; otherwise the actual weight. Normal weight being the actual weight of 50 faultlessly rolled rails.	but calculated weight only paid for.			The finishing temperature in rolling is controlled by the amount of shrinkage not more than $6^7/_{16}$ in. (163·5 mm) allowed per 33 ft. (10·058 m) 75 lb. rail (37·2 kg/m) — with $^1/_{16}$ (1·6 mm) increase per each increase of 5 lbs. (2·5 kg) in the weight of the section.	

ils.

itain		U. S. A.	
ailway	Tramway Rails	Rails	O. H. Rails
eh 9·144, r 18·288 m r 60 ft.) th than	Normal length 10·668, 13·716 or 18·288 m (35, 45 or 60 ft.) $2^1/_2$—$5^0/_0$ shorter as specified $\pm {}^1/_4$ in. (6·3 mm) from the lengths specified	Normal length: 30 and 33 ft. (9·144 and 10·058 m) $10^0/_0$ of order will be accepted in length varying by even feet to 24 feet (7·312m). $\pm {}^1/_4$ in. (6·35 mm) specified length.	
		Square at ends not over $^1/_{32}$ in. (0·8 mm) variation. Must be straight in line and surface.	
·8 mm)	For Fishbolts $^1/_{16}$ in. (1·6 mm)	Must accurately conform to drawing.	
		$^1/_{16}$ in. (1·6 mm)	
		$^1/_{16}$ in. (1·6 mm)	
	$\pm {}^1/_{32}$ in. (0·8 mm). Distance between Fishing angles $\pm {}^1/_{64}$ in. (0·4 mm)	$-{}^1/_{64}$ in. to $+{}^1/_{32}$ in. (0·4 to + 0·8 mm)	
for.	max. 1 lb per yard (0·5 kg/m)	$\pm {}^1/_2{}^0/_0$ accepted and paid for according to actual weight.	
		The finishing temperature in rolling is controlled by the amount of shrinkage not more than $6^7/_{16}$ in. (163·5 mm) allowed per 33 ft. (10·058 m) 75 lb. rail (37·2 kg/m) — with $^1/_{16}$ (1·6 mm) increase per each increase of 5 lbs. (2·5 kg) in the weight of the section.	

FISH PLATES
(Laschen).

Comparative Summary of Specifications for Germany, Great Britain and U. S. A., based on the following data:

a) Standard Specifications for Steel Rails (Einheitliche Vorschriften für Oberbaueisen) of the "Deutsche Verband für Materialprüfungen der Technik", adopted 1904. No. 23, Booklet 1.

b) British Standard Specification for Tramway Rails and Fish Plates No. 2, Revised 1909.

c) Standard Specifications for Steel Splice Bars (Fish Plates), American Society for Testing Materials 1909.

Sub-Committee

		U. S. A.
		Splice Bars
1	Material . . .	—
2	Process of Manu	Bessemer or Open Hearth.
3	Finish	thly rolled and true to template. Sheared accurately ngth and free from fins or cracks and shall ctly fit the rails. Punching and notching shall rately conform in every respect to drawings and dimensions furnished.
4	Chemical analys	Phos not over 0·10.
5	Branding . . .	name of the maker and year of manufacture be rolled in raised letters on the side of the splice bar.
6	Physical Tests:	
	Tensile Test .	00—64.000 lbs. per sq. in. (37·9—45·0 kg/mm²) ngation in 8″ (203·2 mm) not less than 25 %.
	Bending Test:	
	Span	180° flat 
	Permanent Defl	l sized bar first flattened and then bent 180° flat.
	Wedging Test: (Aufkeilprobe)	—
	Number of Tests .	1 test from each blow or melt.

Specifications for Steel Rails.

		Germany		Great Britain			U. S. A.	
		Rails and Tongue Rails	Tramway Rails	Flat Bottom Railway Rails	Bull Head Railway Rails	Tramway Rails	Rails	O. H. Rails
9	Tensile Tests			Diameter (14·3 mm) 0·564 in.	(20·3 mm) 0·798 in.			
	Dimensions of test piece	$^{31}/_{32}$ in. (25 mm) diameter, $7^{7}/_{8}$ ins. (200 mm) length from centre of rail head of pieces which have been subjected to impact test		Area (161·3 mm) $^{1}/_{4}$ sq. in. Gauge length (50·8 mm) 2" Parallel for a length of not less than (57·2 mm) $2^{1}/_{4}$"	(322·6 mm) $^{1}/_{2}$ sq. in. (76·2 mm) 3" (85·7 mm) $3^{3}/_{8}$"	(50·8 mm) 2 ins. long (322·6 mm^{2}) $^{1}/_{2}$ sq. in. approximate sectional area	not called for	
	Tensile strength	min. 39 t. p. sq. in (60 kg/mm^{2})	min. 46 t. p. sq. in (70 kg/mm^{2})	(63—75·6 kg/mm^{2}) 40—48 t. p. sq. in.	(59·9—70·9 kg/mm^{2}) 40—48 t p. sq. in.	(63 kg/mm^{2}) at least 40 t/sq. in.		
	Elongation	To be given		15 % (min.)	15 % (min.)	$10^{1}/_{2}$%		
	No. of tests	1 test for each lot of 200 rails and portion thereof		1 test for each 100 t rails	1 test for each 100 t. rails	1 test for each 100 t. rails		
10	Rejection.	Should the test piece fail to comply with the Impact and Tensile Tests, a second and eventually a third rail is taken from the same cast. Should one of these fail to fulfil the specified requirements, all the rails belonging to such cast may be rejected. The whole delivery can be rejected if on testing no settled conviction is arrived at of the faultless condition of the rails. or, if after the rails are accepted, defects or defaults, arise showing that the rails have not been made in accordance with the specified condition		Should the length cut from the selected rail fail to comply with the drop test specified, two other rails from same cast will be selected, both of which must comply with specified requirements or cast will be rejected Should the test piece fail to comply with the tensile test, 2 other rails may be taken from the same cast, both of which must comply with the specified requirement or cast will be rejected. The Engineer may then take similar thest pieces from two other rails out of the same 100 tons and should either fail whole 100 tons may be rejected		If the test piece fractures under drop test all rails from that cast may be rejected unless it is shown from similar trial on 2 further pieces of rail, that 1st piece was not fairly representative of quality of steel Should test piece fail to comply with tensile test, another rail may be taken from the same cast and it must fulfil specified requirements or cast will be rejected	If any rail breaks under drop test, 2 additional tests will be made from same cast and if either of latter tests fail, all rails of such blow will be rejected	

Specifications for Fish Plates.

		Germany	Great Britain	U. S. A.
		Fish Plates for Railway and Tramway Rails	Fish Plates for Tramway Rails	Splice Rails
7	Rejection of Fish Plates	If 2 from each 100 of a part delivery submitted for acceptance fail to comply with specified requirements the whole of such part delivery may be rejected	(Same as for Tramway Rails) If the first test piece fails to comply with the specifications, another test piece of same cast will be tested	Each blow or melt accepted or rejected on results of tests from that blow or melt
8	Permissible Variations:			
	a) dimensions:			
	In length	$\pm$ 1/8 in (3 mm).	—	Must be rolled true to template
	In position and size of holes	$\pm$ 1/50 in. (0·5 mm)	$\pm$ 1/16 in. (1·6 mm)	
	In bearing face	+ 1/100 in. (0·25 mm)	—	
	In thickness	$\pm$ 1/50 in. (0·5 mm)	—	
	In other dimensions . .	$\pm$ 1/25 in. (1 mm)	—	
	In distance of clinches (Im Abstande der Einklinkungen)	$\pm$ 1/12 in. (2 mm)	—	
	In size of clinches . . .	$\pm$ 1/25 in. (1 mm)	—	
	b) Weight	+ 3% to — 2% Additional weight is paid for up to 1%	Actual weight is paid	Actual weight is paid

lates.

eat Britain	U. S. A.
es for Tramway Rails	Splice Rails
s for Tramway Rails) iecc fails to comply with the er test piece of same cast will be tested	Each blow or melt accepted or rejected on results of tests from that blow or melt
—	Must be rolled true to template
$^1/_{16}$ in. (1·6 mm)	
—	
—	
—	
—	
—	
al weight is paid	Actual weight is paid

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

VIII6

SIMPLIFICATION OF THE METHODS FOR THE TESTING OF STEAM, GAS, AND WATER PIPES MADE OF WROUGHT IRON.

By **A. C. Karsten,** of Copenhagen.

Translated from the German by A. R. Liddell, Charlottenburg.

Professor Hannover, Director of the State Testing Establishment of Copenhagen, made a communication to the Congress which assembled in Brussels in 1906 on some very comprehensive tests on wrought iron steam, gas and water pipes, which were carried out by the Establishment in the first-named city atthe instance of the Danish Society of Engineers, and at the same time gave particulars as to the standards for the delivery of the pipes, which were approved by the above-named society mainly on the ground of the tests in question (see Congress Report C. 3). Since then a series of tests on pipes from various deliveries have been made in accordance with these standards. The results of these later tests made up to August 1st 1909, are put together in the following tables Nos. I and II, and comprise I. steam-pipes, II. gas-pipes, and III. water-pipes.

All the pipes belonging to one and the same delivery are given between two horizontal lines, and the tests with pipes that do not conform to the standards are marked with an asterisk.

An internal-pressure test was not included in the series, because it had been established by earlier experiments, that all the pipes which withstand a bending test are able to bear a much higher internal pressure than the conditions require.

From tables I and II it may be seen, that altogether 49 steam-pipes and 33 gas and water-pipes were tested. 80 tensile and 66 bending tests were made with steam-pipes, and 62 tensile and 46 bending tests with gas and water-pipes. Of the whole number tested, 9 steam and 9 gas and water-pipes dit not prove thoroughly satisfactory, but only three of the former and 5 of the latter category showed grave defects.

To enable these good results to be appreciated it must, however, be mentioned, that the deliveries, from which the sample pipes were chosen, were to be in accordance with the standards laid down, and that the suppliers of the pipes will certainly have endeavoured to obtain these from the best makers; but the results also show that it is possible in the case of deliveries of quite an ordinary character to obtain from the existing works pipes which conform to the standards, while on the other hand tests with pipes from other works of less excellence would hardly be able to produce such good results.

In view of the experiences meanwhile obtained a committee, which was chosen by the Danish Society of Engineers, and over which I have the honour to preside, has drafted out a proposal for a revision of the conditions at present in force.

The text of this proposal is as follows: —

Conditions for the Delivery of Wrought Iron Pipes for Steam, Gas, and Water Services.

§ 1. The pipes are to be as straight as possible, round, and free from rust and visible defects.

The external diameters of light and heavy pipes shall be approximately alike, in order that the same connection-pieces may be made use of for both kinds, without their having to be more deeply cut than is necessary for the attainment of a clean thread.

All threads shall be cleanly cut and of suitable lengths. It is to be recommended that the thread be protected in each case by a muff. Unless otherwise specified, the thread is to be cut after the manner of the German standard pipe-thread*).

The supplies is under obligation, on request, to communicate the name of the works from which the pipes are obtained.

*) See „Hütte“, 1908, Vol I, pag. 668.

§ 2. The weight of the pipes without connection-pieces shall at least fulfil the requirements of the following table:

Nominal Internal Diameter Engl. in.	Corresp. External Diameter mm	Light Pipes		Heavy Pipes	
		Weight per 100 m in kgs.	Corresp. Internal Diameter mm	Weight per 100 m in kgs.	Corresp. Internal Diameter mm
$^3/_8$	16·5	80	12·0	102	10·5
$^1/_2$	20·5	110	15 0	140	13·5
$^3/_4$	26·5	178	21·0	216	19·0
1	33·0	250	26·5	305	24·5
$1^1/_4$	42·0	330	35·0	400	33·0
$1^1/_2$	48·0	413	40·5	495	38·0
$1^3/_4$	52·0	495	44·0	590	42·0
2	59·0	578	51·0	690	49·0
$2^1/_4$	70.0	664	62·0	795	61·0
$2^1/_2$	76·0	750	68·0	902	66·0
3	89·0	925	80·5	1118	78·5
$3^1/_2$	101·5	1098	92·0	1358	89·5
4	114·0	1275	104·0	1550	102·0

The receiver is entitled to refuse, as unacceptable, every pipe the weight of which is more than 5 per cent less than that given in the table.

The receiver is entitled to test the pipes with an internal pressure of 20 atmospheres; the pipes are to be filled with water and the pressure is to be produced by means of a force pump, while the pipe is at the same time to be subjected to gentle blows with a hammer of $^1/_2$ to 1 kg in weight. The receiver is entitled to refuse, as unacceptable, pipes which, on submission to tests of this nature, show cracks or leakages.

§ 3. If patent welded tubes be specified, this refers to pipes of 2 ins. or more in diameter. At the delivery of patent welded tubes the receiver is entitled to require, that after the application of the etching test no butted joint shall be discernible. If seamless tubes be specified, the receiver may demand, that after the etching test has been applied no welded joint shall be discernible.

§ 4. The pipes are to be made of soft ductile material. As a proof of this the material is to be submitted to a tensile and the pipes to a bending test.

a) For pipes of $1^1/_4$ or more in diameter the tensile test is to be made on strips taken parallel to the length direction. The strips are to be 220 mm long by 30 mm broad and are to merge gradually into the head of 35 mm in breadth by 115 mm in length at each of their ends.

They are to be straightened at a dark red heat with a wooden hammer. Two strips are to be taken from each of the pipes to be tested, one from the middle and one from each end of it. The strips must not contain any welded butts.

In the case of pipes of less than $1^1/_4$'' in diameter the tensile test is to be made with pieces of pipe 450 mm in length, the ends of which are closed by plugs.

At these tests the material is to have an ultimate tensile strength of at least 33 kgs. per sq. mm. with a 12 per cent elongation on a measuring length of 200 mm.

b) The bending test is to be made cold on pieces of pipe filled with fine sand and closed at both ends with plugs. The pieces of pipe are to be bent over blocks with corner-radii as given in the following.

For steam-pipes: radius of corner of the block 3 times the nominal internal diameter of the pipe.

For gas and water-pipes: radius of corner of the block 4 times the nominal internal diameter of the pipe.

2'' tubes are to withstand bending to an angle of 120^0, and smaller ones to 90^0 without any injury to the material showing itself.

During the test the welded edge, in the case of a welded tube, shall lie as far as possible to an outer side, that is to say, as far as possible from the plane in which the axis of such tube and the direction of bend are situated.

All the sample pipes are to be taken by the receiver from the material delivered.

§ 5. Should the receiver wish to submit the pipes to a test in accordance with the prescriptions of §§ 3 and 4, he is entitled, himself to determine the number of pipes to be tested. If at least 90 per cent of the tested pipes of each dimension fulfil the conditions contained in §§ 3 and 4, all the pipes are to be regarded as having fulfilled the contract.

Tables of Weights of Heavy Wrought Iron Pipes.

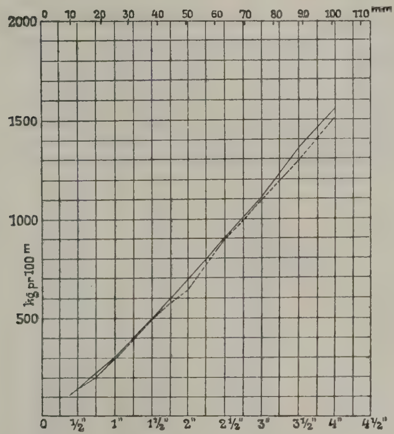


Fig. 1.

········ The Weights of Pipes now customary.

—— The Weights of Pipes proposed in the Standards.

Tables of Weights of Light Iron Pipes.

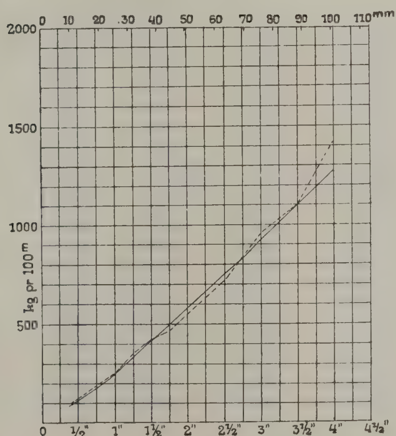


Fig. 2.

········ The Weights of Pipes now customary.

—— The Weights of Pipes proposed in the Standards.

Test Results of Wrought

Sample No.	Diameter of Pipe in Engl. inches	Marks on the Pieces of Pipe	Yield-Point: Wall-Thicknesses in mm	External Diam. or Breadth in mm	Area of section in mm²	Total Load in kgs.	Load in kg/mm²
5784	1	R.	4·3	33·9	399·9	Unclear	—
5785	1	R.	4·4	33·8	406·4	9263	22·8
5786	1 1/2	—	4·5	30·1	135·5	Unclear	—
*)5787	1 1/2	—	4·6	30·0	138·0	—	—
*)5788	2	—	5·2	30·1	156·5	—	—
5789	2	—	5·1	30·1	153·5	3888	25·3
*)5790	3	—	5·3	30·0	159·0	4400	27·7
5791	3	—	5·3	30·0	159 0	4610	29·0
5792	4	—	5·5	30·1	165 6	4113	24·8
5793	4	—	5·6	30·1	168·6	4030	23·9
5794	6	—	6·3	30·0	189 0	c. 4500	c. 23·8
5795	6	—	6·4	30·0	192·0	4350	22·7
6571	2	E.	3·9	29 9	116·6	3675	31·5
6572	2	M.	3·9	29·9	116.6	4138	35·5
6573	2	E.	4·1	29·9	122·6	4000	32 6
6574	2	M.	3·9	29·9	116·6	4110	35·2
6575	1	R. E.	3 4	32 6	311·9	10050	32·2
6576	1	R. M.	3·4	32·6	311·9	10310	33·1
6577	1	R. E.	3·6	33·3	335·9	12315	36·7
6578	1	R. M.	3 6	33·2	334·8	11835	35·3
5764	2	—	4·8	30·0	144·0	Unclear	—
5765	2 1/2	—	5·5	30·0	165·0	4758	28·8
5913	1 1/4	E.	4·3	30·0	129·0	Unclear	—
5914	1 1/4	M.	4·5	30·0	135·0	—	—
5915	2	—	4·9	30·0	147·0	3163	21·5
*)5916	2 1/2	E.	5·0	30·0	150·0	3213	21·4
5917	2 1/2	M.	5·0	30·0	150 0	3180	21·2
5918	1 1/2	E.	4·5	30·0	135 0	Unclear	—
5919	1 1/2	M.	4·7	30·0	141·0	—	—
6175	3/4	R. E.	3·5	26·7	255·1	—	—
6174	3/4	R. M.	3·5	26·7	255·1	—	—
6176	3/4	R. E.	3·3	26·6	241·5	—	—
6177	3/4	R. M.	3·3	26·6	241·5	—	—
6198	2	E.	4·9	29·9	146·5	3953	27·0
6199	2	M.	4·9	29·9	146·5	4508	30·8
6200	2	E.	4·7	29·7	139·6	Unclear	—
6201	2	M.	4·7	29 9	140·5	—	—
6190	3	E.	5·1	30·0	153·0	3868	25·3
6191	3	M.	4·5	30·0	135·0	3405	25·2

*) Test not withstood.

R = Tested piece of pipe.

Iron Steam-Pipes. Table I.

Breaking Point			Observations	Bending Test
Total Load in kgs.	Load in kg/mm²	Percent. of Elongation		
13683	34·2	18·8	—	Test withstood
14708	36·2	25·0	—	"
5050	37·3	16·2	—	"
4783	34·7	9·0	Sample broke in straightening	Broken across
5453	34·8	7·8	"	Test withstood
5605	36·5	14·0	—	"
5760	36·2	9·9	—	—
6195	39·0	15·0	—	—
6110	36·9	13·4	—	—
5998	35·6	15·8	—	—
6575	34·8	18·9	—	—
6420	33·4	—	—	—
5083	43·6	16·2	—	Test withstood
5340	45·8	15·0	—	"
5190	42·3	20·5	—	"
5090	43 7	16·9	—	"
13025	41·8	25·8	—	"
12895	41·3	26·0	—	"
16140	48·1	22·4	—	"
15200	45·4	23·9	—	"
5335	37·0	21·5	—	Test withstood
6000	36·4	25·5	—	"
4575	35·5	21·5	—	Test withstood
4865	36·0	20 3	—	"
4935	33·6	23·3	—	"
4783	31·9	19 7	—	"
4965	33·1	20·5	—	"
4600	34·1	23·7	—	"
4920	34·9	21·5	—	"
9088	35·6	25·4	—	Test withstood
8853	34·7	24·3	—	—
9545	39·5	27·3	—	Test withstood
9563	39·6	27·7	—	—
6340	43·3	26·9	—	Test withstood
6413	43·8	22·2	—	—
5480	39·3	24·3	—	Test withstood
5568	39·6	25·7	—	—
5515	36·0	17·5	—	—
5065	37·5	19·2	—	—

E and M = Tested piece of pipe or strip taken from the end of the pipe within the thread or from the middle of the pipe respectively.

Sample No.	Yield-Point						
	Diameter of Pipe in Engl. inches	Marks on the Pieces of Pipe	Wall-Thicknesses in mm	External Diam. or Breadth in mm	Area of section in mm²	Total Load in kgs.	Load in kg/mm²
6192	3	E.	4·7	29·9	140·5	3448	24·5
*)6193	3	M.	4 9	29·9	146·5	3508	23·9
7020	3/4	R. E.	2·9	26·6	215·9	—	—
7021	3/4	R. M.	3·0	26·6	222·4	—	—
7022	3/4	R. E.	3·0	26 3	219·6	—	—
7023	3/4	R. M.	3·0	26·2	218·6	—	—
7024	1 1/4	E.	3·7	30·0	111·0	—	—
7025	1 1/4	M.	3·8	30·0	114·0	—	—
7026	1 1/4	E.	3·6	30·0	108·0	—	—
7027	1 1/4	M.	3·7	30·1	111·4	—	—
7028	3/4	R. E.	3·7	26·4	263·9	—	—
7029	3/4	R. M.	3·7	26·4	263·9	—	—
7030	3/4	R. E.	3·5	26·5	252·9	—	—
7031	3/4	R. M.	3.6	26·5	258·9	—	—
7032	1 1/4	E.	4·4	30·1	132·4	—	—
7033	1 1/4	M.	4·4	30·1	132·4	—	—
7034	1 1/4	E.	4·5	30·1	135·5	—	—
7035	1 1/4	M.	4·5	30·1	135·5	—	—
7036	2	E.	5·1	30·1	153·5	—	—
7037	2	M.	5·0	30·1	150·5	—	—
7038	2	E.	4 4	30·2	132 9	—	—
7039	2	M.	4·4	30·1	132·4	—	—
7183	2	—	5·0	30·0	150·0	—	—
7184	2 1/2	—	5·2	30·0	156·0	—	—
7185	3	—	5·2	30·0	156·0	—	—
*)8258	2	E.	3·6	29·9	107.6	c. 2380	c. 22·1
*)8259	2	M.	3·8	29·9	109·6	2874	26·2
8260	1 3/4	E.	3·9	29·8	116·2	c. 2760	c. 23·8
8261	1 3/4	M.	4·0	29·8	119·2	c. 2780	c. 23·3
8262	1 1/2	E.	3·8	29 6	112·5	2690	23·9
8263	1 1/2	M.	4·0	29·8	119·2	2824	23·7
*)8264	1 1/4	E.	3 6	29·9	107·6	2365	22·0
8265	1 1/4	M.	3·7	29·7	109 9	2518	22·9
8266	1	R. E.	3·2	33·2	301·6	8090	26·8
8267	1	R. M,	3·2	33 2	301·6	8115	26·9
8268	3/4	R. E.	2 8	26·7	210·2	5340	25·4
8269	3/4	R. M.	2·8	26·7	210·2	5380	25·6
*)8270	1/2	R. E.	2·5	20 7	142·9	4090	28·6
8271	1/2	R. M.	2·5	20·8	143·7	4145	28·8
*)8272	3/8	R. E.	2·7	17·0	121·3	3390	27·9
8273	3/8	R. M.	2·7	16·9	120·4	3400	28 2

*) Test not withstood.

R = Tested piece of pipe.

Breaking Point			Observations	Bending Test
Total Load in kgs.	Load in kg/mm^2	Percent. of Elongation		
4700	33·5	14·2	—	—
4613	31·5	11·7	—	—
7675	35·5	16·8	—	Test withstood
7750	34·9	22·2	—	"
8375	38·1	23·8	—	"
8110	37·1	26·9	—	"
3975	35·8	17·2	—	"
4165	36·5	19·7	—	"
3705	34·3	14·9	—	"
4010	36·0	22·7	—	"
8730	33·1	23·7	—	"
8950	33·9	19·7	—	"
8645	34·2	26·3	—	"
8950	34.6	28·3	—	"
4910	37·1	16·7	—	"
5020	37·9	14·2	—	"
4480	33·1	16·2	—	"
4788	35·3	18·9	—	"
5320	34 7	17·8	—	"
5240	34·8	17·8	—	"
4400	33·1	21·5	—	"
4405	33·3	12·2	—	"
5680	37·9	23·9	—	Test withstood
5575	34 4	13·7	—	"
5563	35 7	23·0	—	"
3655	34·0	14·3	—	Broken across
4011	36·9	18·0	Bent over block 4×intern. diam.	Unimportant transverse crack
4023	34·6	14·4	—	Test withstood
4213	35·3	22·2	—	"
4025	35·8	16·3	—	"
4288	36·0	23·0	—	"
3484	32·4	12·2	—	"
3846	35·0	18·0	—	"
11390	37 8	14·8	—	"
11510	38 2	16·4	—	"
7620	36·3	22·3	—	"
7800	37·1	15·9	—	"
5040	35·3	7·8	—	"
5020	34·9	—	Fracture beyond the testing zone	"
4718	38 9	17·3	—	Unimportant transverse crack
4626	38 4	12·2	—	Test withstood

E and M = Tested piece of pipe or strip taken from the end of the pipe within the thread or from the middle of the pipe respectively.

The Results of

Sample No.	Yield-Point						
	Diameter of Pipe in Engl. inches	Marks on the Pieces of Pipe	Wall-Thick-nesses in mm	External Diam. or Breadth in mm	Area of section in mm^2	Total Load in kgs.	Load in kg/mm^2
4893	1/2	R. E.	3·5	20·6	188·0	5063	26·9
4894	1/2	R. M.	3·6	21·0	196·8	5180	26·3
4895	3/4	R. E.	4·1	26·4	287·2	c. 6000	c. 20·9
4896	3/4	R. M.	4·1	26 6	289·8	6780	23·4
4897	1	R. E.	4·3	33·4	393·1	8550	21·8
4898	1	R. M.	4·3	33·3	391·7	8835	22·6
*)4899	1 1/4	E.	4·5	30·0	135·0	2900	21·5
4900	1 1/4	M.	4·5	30·0	135·0	3280	24·3
*)4901	1 1/2	E.	5·3	30·0	159·0	3950	24·8
*)4902	1 1/2	M.	5·1	30·0	153·0	c. 3950	25·8
4903	2	E.	5·5	30 0	165·0	4088	24·8
4904	2	M.	5·8	30·0	174 0	4310	24·8
*)4983	1 1/4	E.	3·5	30·0	105·0	2088	19·9
4989	1 1/4	M.	3·5	29·9	104·7	2313	22·1
4990	1 1/4	E.	3·7	30 0	111 0	Unclear	—
4991	1 1/4	M.	3·6	30·1	108·4	—	—
4992	1 1/2	E.	3·6	30·1	108·4	—	—
4993	1 1/2	M.	3·8	30·1	114·4	2618	22 9
4994	1 1/2	E.	4·0	30·1	120·4	2688	22·3
4995	1 1/2	M.	4·0	30·0	120·0	Unclear	—
4996	2	E.	4·3	30 1	129·4	c. 2850	c. 22·0
4997	2	M.	3·9	30·0	117·0	2925	25·0
4998	2	E.	4·3	30·0	129·0	Unclear	—
4999	2	M.	4·3	30·1	129·4	—	—
*)5072	3/4	R. E.	3 9	26 0	270·7	5333	19·7
*)5073	3/4	R. M.	3·9	26·3	274·5	5125	18·7
5074	1 1/4	E.	4·0	30 0	120·0	c. 2800	c. 23·3
5075	1 1/4	M.	4·0	30 0	120·0	Unclear	—
5076	2	E.	4·0	30·0	120·0	c. 2838	c. 23·7
5077	2	M.	4·5	30·0	135·0	c. 2958	21·9
6234	3/4	R.	3·6	26·7	261·3	Unclear	—

*) Test not withstood.

R = Tested piece of pipe.

Wrought Iron Steam-Pipes.

Table II.

Breaking Point			Observations	Bending Test
Total Load in kgs.	Load in kg/mm²	Percent. of Elongation		
7403	39·4	16·7	—	Test withstood
7495	38·1	16·3	—	„
10613	37·0	23·7	—	„
10370	35·8	21·8	—	„
13488	34·3	16·2	—	„
14248	36·4	23·5	—	„
4050	30·0	—	Fracture beyond the testing zone	Broken across
4638	34·4	13·2	Throughgoing crack in a head	Test withstood
5288	33·3	10·3	Several cracks	Welded butt slightly opened
5378	35·2	12·5	Cracks in the heads	Welded butt opened considerably
5788	35·1	15·9	„	Test withstood
5898	33·9	14·7	—	„
3293	31·3	22·0	—	Test withstood
3525	33·7	22·4	—	„
3815	34·4	20·3	—	„
3750	34·6	21·5	—	„
3680	33·9	15·0	—	„
3728	32·6	18·3	—	„
3893	32·3	22·5	—	„
3940	32·8	21·4	—	„
4480	34·6	18·3	—	„
4215	36·0	20·7	—	„
4418	34·2	22·3	—	„
4453	34·4	19·8	—	„
8665	32·0	27·9	—	Test withstood
8573	31·2	25·0	—	„
4338	36·2	22·5	—	„
4245	35·4	17·0	—	„
4035	33·6	17·3	—	„
4523	33·5	18·5	—	„
9308	35·6	12·3	—	Test withstood

E and M = Tested piece of pipe or strip taken from the end of the pipe within the thread or from the middle of the pipe respectively.

Sample No.	Diameter of Pipe in Engl. inches	Marks on the Pieces of Pipe	Wall-Thicknesses in mm	External Diam. or Breadth in mm	Area of section in mm²	Total Load in kgs.	Load in kg/mm²
	Yield-Point						
*) 6235	3/4	R.	3·4	25·6	237·1	6018	25·4
6236	1	R.	3·7	32·9	339·4	8990	26·5
6237	1	R.	3·6	33·0	332·5	c 9500	28·6
6179	3/4	R. E.	2·7	26·5	201·8	Unclear	—
6178	3/4	R. M.	2·7	26·5	201·8	5618	27·8
6180	3/4	R. E.	2 7	26·5	201·8	Unclear	—
6181	3/4	R. M.	2·7	26·5	201·8	—	—
6182	1	R. E.	3·6	32·7	329·1	7528	22·9
6183	1	R. M.	3·6	32·7	329·1	7590	23·1
6185	1	R. E.	3·4	32·7	312·9	7375	23·6
6184	1	R. M.	3·4	32·7	312·9	7413	23·7
6210	1 1/4	E.	3·8	29·9	113·6	2675	23·5
6211	1 1/4	M.	3·8	29·9	113·6	2645	23·3
6212	1 1/4	E.	4·0	29·9	119·6	2675	22·4
6213	1 1/4	M.	3·7	29·9	110·6	2623	23·7
6206	1 1/2	E.	4·5	29·9	134·6	3180	23·6
6207	1 1/2	M.	3·9	29·9	116·6	2700	23·2
6208	1 1/2	E.	3·9	29·9	116·6	2888	24·8
6209	1 1/2	M.	3·9	29·9	116·6	2875	24·7
6194	2	E.	4·5	29·9	134·6	4435	32·9
6195	2	M.	4·4	29·9	131·6	Unclear	—
6196	2	E.	4·3	29·9	128·6	3525	27·4
6197	2	M.	3·6	29·9	107·6	3033	28·2
*) 6202	2 1/2	E.	4·1	29·8	122·2	3175	26·0
*) 6203	2 1/2	M.	4·4	29·9	131·6	3345	25·4
6204	2 1/2	E.	4·2	29 9	125·6	2983	23·8
6205	2 1/2	M.	4·2	29·8	125·6	2795	22·3
6186	3	E.	4·1	30·0	123·0	2660	21·6
6187	3	M.	4·1	29·9	122·6	2740	22·3
6188	3	E.	4·1	30·0	123 0	3040	24·7
6189	3	M.	4·4	30·0	132·0	3190	24·2

*) Test not withstood.

R = Tested piece of pipe.

Breaking Point			Observations	Bending Test
Total Load in kgs.	Load in kg/mm²	Percent. of Elongation		
8105	34·2	11·8	—	Test withstood
12863	37 9	17·8	—	"
12175	36·6	13·5	—	"
8135	40·3	21·0	—	Test withstood
8170	40·5	21·2	—	—
7730	38·3	21·3	—	Test withstood
7550	37·4	24·9	—	—
11875	36·1	26·7	—	Test withstood
11700	35·6	30·0	—	—
11348	36·3	17·3	—	Test withstood
11383	36·4	20·5	—	—
4018	35·4	21·7	—	Test withstood
4080	35·9	23 8	—	—
4168	34·9	20·9	—	Test withstood
3960	35·8	19·3	—	—
4670	34·7	23·5	—	Test withstood
4238	36·3	19·2	—	—
4283	36·7	19·0	—	Test withstood
4170	35·8	16 5	—	—
5025	37·3	28·7	—	Test withstood
4613	35·1	22·5	—	—
4633	36·0	26·8	—	Test withstood
4075	37·9	19·2	—	—
4145	33·9	6·8	—	Test withstood
4500	34·2	7·9	—	—
4370	34.8	18·2	—	Test withstood
4373	34·9	17·0	—	—
4098	33·3	19·8	—	—
4150	33·8	17·4	—	—
4515	36 7	22·5	—	—
4895	37·1	18·5	—	—

E and M = Tested piece of pipe or strip taken from the end of the pipe within the thread or from the middle of the pipe respectively.

In the case of pipe dimensions in connection with which this condition may not be fulfilled, 2 per cent of the pipes of the size in question, but not fewer than 5 and not fewer than the number tested in the first instance, are to be chosen. Unless at least 90 per cent of the pipes thus chosen fulfil the conditions, all the pipes of these sizes are to be regarded as unacceptable.

The first test—including the value of the pipes tested — is to be paid for by receiver. Should additional tests be made, these are to be paid for by the supplier, who is to receive no compensation for the pipes used up at these tests.

Strictly speaking, these new standards differ from those formerly framed only in an unimportant alteration in the determination of the weight, and in a provision inserted in § 5 in reference to the number of the test-sample pipes, etc.

The above-mentioned tests of Table I do not include determinations of weight.

As may be seen from the diagram giving the weight of the German pipes at present in most extensive use, these weights are not in proportion to the dimensions of the pipes; in the weights proposed for the standards the endeavour had been made to attain a constant proportion of the kind, and this with the same external diameter as was proposed by several German Societies of Engineers (See Hütte 1908, Vol. I, p. 668). In consideration of the durability of lines of piping specially exposed to wear and tear, the Danish Society of Engineers has also made out a table of weights for the so-called heavy pipes.

The proposal is accordingly laid before the Congress, that, after discussion and eventual alteration, these standards be recognised as international; should the Congress consider the material here forthcoming to be insufficient, it is moved that this body submit it to further treatment in an international committee. and draw up new conditions.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

X11

ON THE BEST MANNER OF DETERMINING THE COMMENCEMENT AND THE TIME OF SETTING.

Hardness Test, by **H. Laborbe,** Us. St. Germain near Beffes, France.

Translated from the French by H. Borns, London.

Everybody knows how little the estimates of the time of setting are in accord. „They vary“, as Mr. Mesnager has remarked, „from single to double without our being able to state the reasons.“

Conventionally we measure in practice the end of the setting period, either by the thumb test, or by the needle test. The two methods are based upon the paradoxical principle that we accept, by convention, the observation of a fact at the very moment when this fact ceases to exist. In Mr. Henry Le Chatelier's opinion the setting test should be a resistance test, and it is for this reason that I propose a hardness test, because we then study the setting in its principal effect.

I make use for this purpose of the well-known device of the metallurgist, the steel ball which is pressed against a plane surface of the hydraulic material.

I. Comparison of the Results given by the Thumb Test, the Needle Test and the Hardness Determination.

The results of the comparison will be understood from Fig. 1., in which the numbers correspond and in which times are counted from the gauging operation. As regards the needle test,

when is the setting to be declared complete? After test 1, 2, 3, 4, or later still? It is purely a question of a needle mark, varying „du simple au double, sans qu'on puisse en dire la raison", as Mr. Mesnager has written concerning the results of such needle tests.

Fig. 1. Cement, gauged with 34·5 per cent of water.

Test	Thumb Test	Vicat Needle Test	Ball Test	Diameter of Impression
1	$50'$	$52'$	$54'$	13 mm
2	$55'$	$57'$	$59'$	11·5 „
3	1^{h}	$1^{h}\,2'$	$1^{h}\,4'$	10·7 „
4	$1^{h}\,5'$	$1^{h}\,7'$	$1^{h}\,10'$	9·6 „

With the thumb, no hesitation is possible. After test 4 the setting is complete. In the case of the ball test we have in addition an objective measure of the phenomenon; we need only determine the dimension of the impression.

II. Hardness Number.

By definition I call hardness number Δ the ratio

$$\Delta = \frac{S}{P} \tag{1}$$

of the pressure put upon the ball to the spherical surface of the impression. This ratio is an absolute number, giving for any moment T a constant of the hydraulic material under investigation.

This ratio Δ is easily ascertained. We have the following relations between R, the radius of the ball, and r und h, the radius and depth of the impression.

$$S = 2\pi R h \tag{2}$$

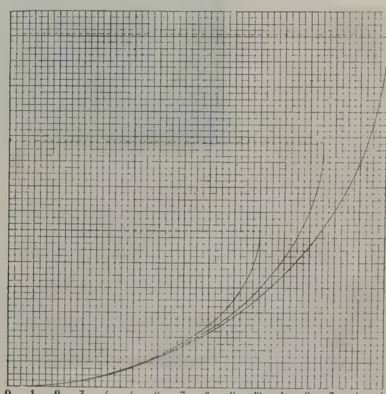
$$r^2 = h(2R - h) \tag{3}$$

from which we eliminate h. It should be remarked that while the determination of h cannot be effected with any precision, there is, on the other hand, with the actually applied pressures, no deformation of the steel ball. The impression will hence be truly spherical and we arrive at the following equation for s and r:

$$S^2 + 4\pi^2 R^2 r^2 - 4\pi R^2 S = 0. \tag{4}$$

When we plot the S as ordinates and the r as abscissae, this equation represents an ellipse, passing through the origin and having its centre on O S at the distance $2\pi R^2$ and its small semiaxis horizontal in a length $r = R$.

This ellipse can easily be constructed with the desirable degree of accuracy (see plate 1). For each abscissa r we shall have a corresponding value of S which, when substituted in equation (1), will give the coefficient of hardness of the material for the moment T. To the left of O S we might construct the equilateral hyperbola $\Delta S = P$ whose abscissae would, for each value of S, allow us to read off, by one observation, the corresponding coefficient Δ. More simply we might start from an arbitrary zero hardness and



Pl. 1.

might deduce, as fourth proportionals, the hardness values corresponding to a certain number of impressions: e. g., 14, 13, ... 4 mm. By dividing the intervals thus obtained into ten equal parts we could trace a straight line parallel to O S, which would enable us to read off the coefficient Δ corresponding to any particular value of S.

Under general circumstances, however, these two solutions will not constitute a great simplification. We see indeed that ultimately Δ varies with P and R. We should, therefore, make as many constructions as there are P and R possible. On the other hand, these constructions, and in particular the second one may be extremely useful, provided we choose the zero suitably for making a convenient hardness scale, in the case of ball tests conducted under a definite pressure.

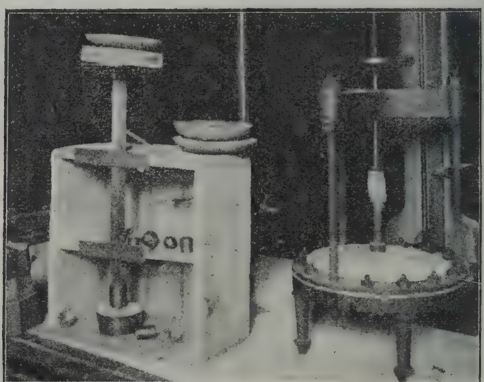


Fig. 2.

III. Investigation of the Mode of Operation.

1. The Apparatus for Applying the Pressure. I have first worked with a Thomasset gauge press (Fig. 2). There is always a slight torsional movement with that instrument, leading to the formation of circular fissures about the impression, e. g., Fig 1, impression 1.

My time being limited, I had to confine my experiments to seven days at the maximum. It was then possible to operate with a kind of big Vicat needle, a model of which will be seen on the left of fig. 2. The rod of the needle, the upper plate, and the movable system holding the ball are accurately scaled to 1 kg;

lead weights of 4 and 5 kg respectively permit of loading the apparatus and of making experiments at 5, 10, 15, 20 kg. Pressures of 7 or 8 kg will suffice in all cases. There is hence no need of expensive apparatus; a Michaelis balance, provided with an inversion apparatus, will almost always be all that is required. For greater forces the hydraulic press of Messrs. L. and H. Le Chatelier will be amply sufficient; this press may conveniently be standardised with the aid of a Guillery apparatus. The adjustable mounting of the ball (see Fig. 2) can casily be adapted to all these apparatus.

2. Diameter of the Ball. I have experimented with diameters of 10, 20, 25, 30 mm. The two first ones are too small; the marks are slight, the balls are forced beyond the equator of the ball and circular fissures round the ball are more frequent. The diameter of 30 mm seems to be the most suitable, at least for neat tests; mortars give better distinct impressions with balls of 25 mm. Too large diameters yield impressions with badly defined borders; an area of depression is often produced with more or less accentuated circular fissures.

3. Measurement of the Impressions. I have made use of a caliper gauge with 0,1 mm vernier; the heads should be bevelled for facilitating the observations. The angular scale of H. Le Chatelier is likewise very practical. If the curves of plate I are to be utilised for the calculation of the spherical surfaces, a proportional compass, with points or jaws, will prove convenient, as it will enable the experimenter to plot the r directly on the diagram without taking readings or dividing.

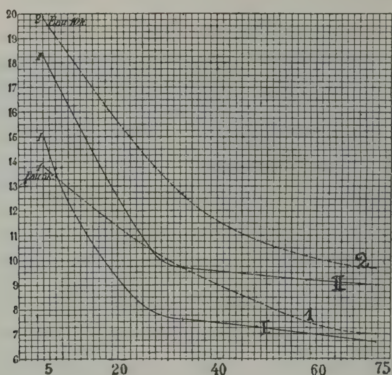
It would be illusory to make use of an apparatus giving an approximation superior to 1/20 of a millimetre.

4. State of the Surface. The surface should evidently be plane. But it will be sufficient to smooth it at the moment when the mould is being charged by placing a plate of glass on the top of it. Specimens, which have already hardened and not been prepared in this manner, should be given a slight polish with the aid of emery paper.

5. Influence of the manner in which the setting has taken place. Table I and the corresponding diagram give the results for two specimens of lime, I and II, hardened in the air, and two specimens, 1 and 2, hardened under water, all conditions being otherwise equal.

Table I. Ball 30 mm

T	Pressure 5 kg		Pressure 10 kg	
	D	D	D	D
	Air	Water	Air	Water
5	15·0	13·8	18·3	19·9
24	8·0	11·0	12·0	14·6
29	7·8	10 0	9·7	13·2
33	7·6	9·7	9·6	12·7
48	7·3	8·5	9·5	10·9
58	7·0	7·3	9·2	10·2
72	6·7	7·0	9·0	9·7
	I	1	II	2



It will be seen that a thin, superficial layer appeared to set very rapidly by the evaporation of water, but that this layer was by itself incapable of sustaining the pressure of the ball. It is crushed in the first tests, giving rise to the observed deformations and producing an abnormal impression, while in the final tests this superficial layer reinforces the strata below in a regular manner making them, set as if they were under water. With the Vicat needle we note simply that no impression is made on the superficial layer after the fifth hour, the rest of the phenomenon escapes observation.

6. Influence of the Thickness of the Pat. Table II demonstrates that, within the limits of the observations, the thickness of the pat under examination has no influence.

Table II. Ball 30 mm. P = 15 kg

T	Thickness of the Pat.			
	33 mm	40 mm	45 mm	50 mm
3	24·6	23·8	23·9	24·4
18	17·0	16 7	17·2	16·9
24	16·6	15·7	15·0	15·5
27	15·0	14·6	14·8	15·3
42	14·0	13·0	13·0	14·1
48		12·4	12·2	13·4
51		12·3	12·0	12·8
66		11·6	11·8	11·8
72		11·3	11·3	11·7
75		10 4	11·3	11·7
96		10·2	10·4	11·6
120			9·7	10·2
168		9·0	9·2	9·6
		60 IX		

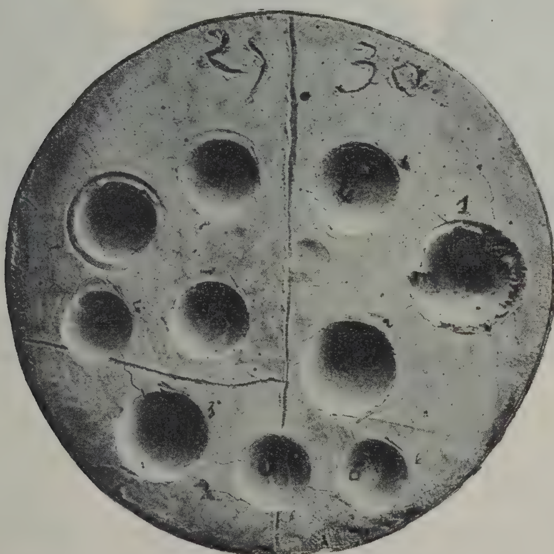


Fig. 3.

In practice whe should use a thickness at least twice or $2^1/_2$ times as great as the depth of the impression. If this precaution is neglected the surface assumes an undulating appearance like a soil in which foundations are laid in moving ground.

7. Influence of the Impressions upon one another of walls of the mould, etc. Fig. 3 illustrates a series of accidents, which observation of the following precautions would avoid; care is particularly to be taken when experimenting soon after gauging.

Take a clean ball, slightly greasy (impression 1 is jagged). Keep the impressions apart from one another and from the wall of the receptacle (as pointed out above, impressions 5 and 6 are oval). Have a sufficient pat thickness (the surface is undulated between 1, 2, 4). Perpendicular fractures in the impression, cracking between the impressions and the wall (6), due either to insufficient spacing between the impressions and the wall, as already explained, or to too brisk an application of the pressure. It is useless to keep the weights on too long; 8 or 10 seconds will as a rule suffice to effect equilibrium.

Fig. 4. Ball of 30 mm. Exper 60—VII, 60—VIII, 60—IX.

IV. Investigation of the Influence of the Diameter of the Ball, of the Pressure. Relation between $\triangle$ and T. Comparability of the Tests. Approximation.

Table III, the photographs of Fig. 4, and the diagrams belonging to them give the results of 116 tests, for periods ranging from 3 to 168 hours, with steel balls of 20, 25, 30 mm under pressures of 5, 10, 15 kg on an hydraulic lime of average commercial quality. I have calculated the spherical surfaces and the ratio $\triangle = \frac{P}{S}$, and I have constructed for each ball a series of three curves corresponding to the pressures of 5, 10, 15 kg.

When we select an instant T, we recognise that $\triangle$ is not the same for all the balls and for all the pressures. It varies with

Ball 30 mm

Exp. 60—VII		P = 10 kg. Exp. 60—VIII			P =
S	$\Delta = \frac{P}{S}$	D	S	$\Delta = \frac{P}{S}$	D
2·30	2·173	20·30	3·75	2·69	25·
1·12	4·460	14·20	2·20	4·09	16·
0·90	5 550	13·00	1·46	6·84	15·
0·80	6·250	12·90	1·45	6·89	14·
0·60	8·330	12·70	1·40	7·42	13
0·50	10·000	10·50	0·90	11·11	12·
0·50	10 000	10·00	0·83	12·04	12·
0·47	10·630	9 90	0·78	12·82	11·
0·40	12·500	9·90	0·78	12·82	11·
0·38	13·150	9·80	0·76	13·15	10·
0·36	13·880	9·30	0·70	14·28	10·
0·35	14·280	8·70	0·60	16·66	—
0·27	18·150	7 90	0·50	20·00	9·

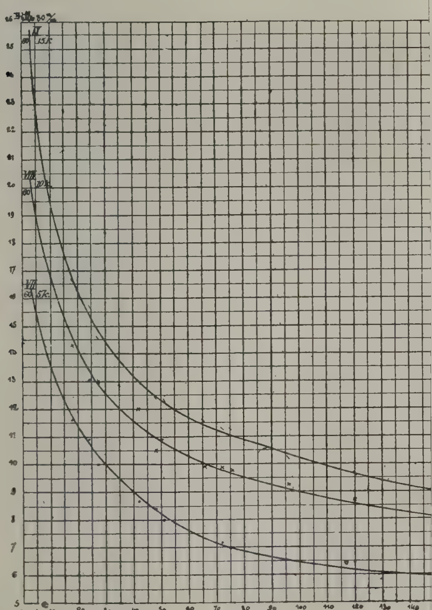
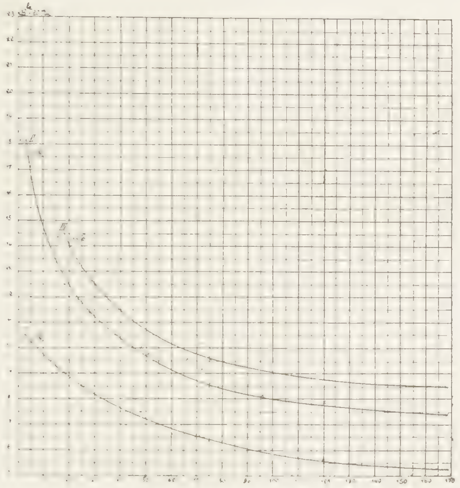
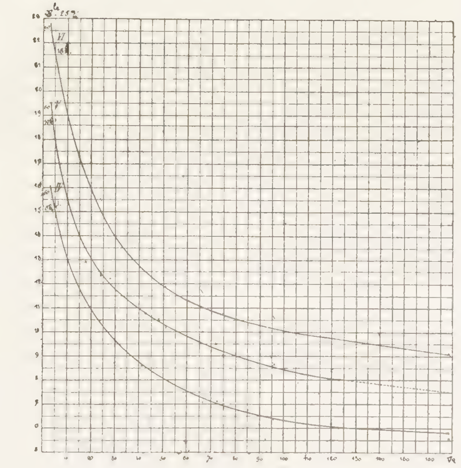
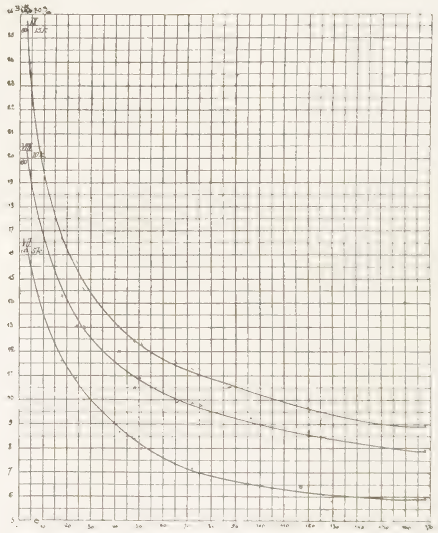


Table III.

Number	Time	Ball 20 mm									Ball 25 mm									Ball 30 mm									Corresponding indication of the Vicat needle
		P - 5 kg. Exp. 60—I			P — 10 kg. Exp. 60—II			P — 15 kg. Exp. 60—III			P — 5 kg Exp. 60—IV			P = 10 kg. Exp. 60—V			P = 15 kg. Exp. 60—VI			P 5 kg. Exp. 60—VII			P — 10 kg. Exp. 60—VIII			P = 15 kg. Exp. 60—IX			
		D	S	$\Delta = \frac{P}{S}$	D	S	$\Delta = \frac{P}{S}$	D	S	$\Delta = \frac{P}{S}$	D	S	$\Delta = \frac{P}{S}$	D	S	$\Delta = \frac{P}{S}$	D	S	$\Delta = \frac{P}{S}$	D	S	$\Delta = \frac{P}{S}$	D	S	$\Delta = \frac{P}{S}$	D	S	$\Delta = \frac{P}{S}$	
1	3	10·50	0·95	5·26	18·20	3·65	2·73	—	—	—	16·10	2·35	2·12	19·60	3·48	2·90	22·80	5·95	2·52	16·30	2·30	2·173	20·30	3·75	2·69	25·80	6·95	2·15	Needle penetrates to depth of 20 mm
2	18	9·10	0·68	7·35	12·50	1·65	6·06	14·50	1·95	7 69	10 60	0·98	5·10	12·90	1·50	6·66	16·40	2·40	6·25	11·60	1·12	4·460	14·20	2·20	4·09	16·70	2·55	5·88	" " " " " 1 "
3	24	8·40	0·63	7·93	12·00	1·30	7·69	13·30	1·66	9 03	10·50	0·95	5·26	12·30	1·35	7·40	15·50	2·05	7·31	10·90	0·90	5 550	13·00	1·46	6·84	15·70	1·95	7·69	" " " " " 1/10 "
4	27	8·20	0·58	8·62	11·40	1·18	8·47	12·70	1·45	10·34	9·50	0·75	6·66	12·30	1·35	7·40	14·20	1·75	8·57	10·00	0·80	6·250	12·90	1·45	6·89	14·60	1·85	8·10	No change
5	42	8·00	0·53	9·09	10·00	0·87	11·49	—	—	—	8·60	0-63	7·93	11·90	1·25	8·00	12·70	1·40	10·71	8·70	0·60	8·330	12·70	1·40	7·42	13 00	1·40	10·71	" "
6	48	7·50	0·45	11·11	9·80	0·85	11·76	11·00	1·05	14·28	7·60	0·50	10·00	10 50	0·92	10·86	12·00	1·25	12·00	8·40	0·50	10·000	10 50	0·90	11·11	12·40	1·30	11·53	" "
7	51	7·30	0·43	11·12	9·60	0·82	12·19	10·60	0·95	15·78	7·40	0·45	11·11	10·20	0·88	11·36	11·90	1·22	12·29	8·00	0·50	10 000	10·00	0·83	12·04	12·30	1·27	11·81	" "
8	66	6·70	0·37	13·51	9·50	0·80	12·50	10·20	0·90	16·66	7·10	0·40	12·50	10·00	0·84	11·90	11·70	1·20	12·50	7·80	0·47	10·630	9 90	0·78	12·82	11·60	1·15	13·04	" "
9	72	6·60	0·35	14·28	9·20	0·72	13·88	10·20	0·85	17·64	7·10	0·40	12·50	9·50	0·75	13·33	11·30	1·13	13·27	7·20	0·40	12·500	9·90	0·78	12·82	11·30	1·10	13·63	" "
10	75	6·40	0·32	15·60	8·60	0·65	15·38	9·60	0·80	18·75	6·90	0·37	13·51	9·00	0·67	14·92	10·70	1·00	15·00	7·00	0·38	13·150	9·80	0·76	13·15	10·40	0·85	17·64	" "
11	96	6·10	0·30	16·66	8·20	0·60	16·66	9·30	0·70	21·42	6·50	0·35	14·28	8·60	0·60	16·66	10·60	0·95	15·78	6·70	0·36	13·880	9·30	0·70	14·28	10·20	0·80	18·75	" "
12	120	5·60	0 26	12·23	7·90	0·50	20·00	9·20	0·68	22·05	6·30	0·32	15·62	8·40	0·55	18·18	10·00	0·85	17·64	6·50	0·35	14·280	8·70	0·60	16·66	—	—	—	" "
13	168	5·30	0·22	22·72	7·40	0·45	22·22	8·50	0·65	23·07	5·90	0·28	17·89	5·50	0·25	40 00	9·10	0·68	22·00	5·90	0·27	18·150	7 90	0·50	20·00	9·00	0·68	22·05	" "







R and P. It is as with steel specimensfor which Benedicks has established the relations:

$$\Delta \sqrt[5]{R} = c$$

$$^0\Delta = \Delta \cdot \frac{1 + P^0}{1 + P.}$$

It would appear that these relations hold equally well for hydraulic materials (thus for T = 3 hours, we find as extreme values for the former 2·23 and 2·36). But we only possess, for each T, three observations with different R and three with different pressures; that is sufficient for an absolute verification. Moreover, in the case of hydraulic cements there is one more variable to be considered than in the case of steel, namely the time. When we plot instead of the diameters, the Δ as ordinates, we obtain curves which are convex with regard to the positive ordinate and, to judge by their form, it would appear possible to deduce a relation between Δ and T analogous to the relation which Benedicks found for Δ and P. In any case the curves admit of making the following statements:

α) Of the 116 impressions (to which we might add the 31 impressions of Table II and the 14 under water of Table I) a single one only, 111—5 has been annulled on account of a defect in the paste. In another one, 111—1, the mounting of the ball had touched the insufficiently consistent paste, and V—13 was disregarded as a faulty experiment. It is, therefore, easy to conduct the operations and to prepare the specimens.

β) I have marked the real experimental points on the diagrams. When we consider those which deviate most from the mean curve: curve VIII—5 in experiment 110, 6 in 120, curve II—7 in 90, 8 in 95, curve VI—7 in 115, curve V—5 in 100; curve IV—6 in 80, we arrive at an approximation which is worth considering in another sense than that which Mr. Mesnager expressed in the words quoted at the beginning of this communication with regard to the Vicat needle test.

γ) In Table II (ball of 30 mm, pressure of 15 kg) is to be seen the column 60—IX of Table III; on the other hand if we compare in Table I the columns 60—VII and 60—VIII columns where we operated with the same ball and the same pressures, it will be seen that these results are concordant within the ex-

perimental errors. Now all these tests, conducted at intervals of 15 or 20 days, have been made with the same ordinary hydraulic lime of good commercial quality, which had at the commencement of the experiments, been placed in earthenware pots which were kept well stoppered so as to remain similar to itself during the whole period of the experiments.

We may therefore conclude:

"The hardness test, conducted as indicated above, is simple to perform and practical; it yields precise and concordant results."

V. Tests lasting more than 7 days.

It is certain that the determination of the hardness has a greater value than a mere setting test. The determination supplics one of the constants of the cements studied, and it would be most interesting to continue the experiments for more than seven days and to enquire in particular into any connection between the coefficient of hardness and the values of tension and compression tests.

I hope to place some results to this effect before the Congress.

One question suggested itself, however: up to which moment will the ball produce an impression? In view of the small porosity and elasticity of neat pats which have attained a certain degree of hardness, one might ask whether the period of elastic deformation would not, at that moment, be so short as to make the specimen break, before an impression could be formed.

Thanks to the kindness of Mr. Enault, engineer to the City of Paris, and of Mr. Anstett, chief of the testing laboratories of the City of Paris, I have been able to experiment with specimens that had been hardening for 90 days. Further, Mr. Mesnager has been kind enough to place at my disposal some much older briquettes which I have crushed in his laboratory in conjunction with Mr. Mercier. Here are the results of these experiments.

We can conclude from these data that, after 90 days, we shall obtain good observations. When going beyond that we cannot be equally sure. The impressions are often not well defined and fractures will ensue under variable pressures. The rapidity with which the pressure is increased exercises apparently a considerable influence; but it must be stated that the metallic pressure gauge is hardly an instrument of precision, suited for such experiments.

Nature of the Material	Age	Ball	Pressure	Diam. of impression	Observations
Roman cement	90days	30 mm	350 kg	8·6 mm	Specimen broken under 455 kg
„ „	90 „	25 „	300 „	7·0 „	Not broken
Vassy cement	90 „	30 „	200 „	7·8 „	Broken under 400 kg
„ „	90 „	25 „	200 „	7·6 „	Not broken
Artificial P. cement	90 „	30 „	500 „	5·5 „	„ „
Slag cement	1 year	30 „	730 „	4·4 „	One specimen breaks under these conditions, another does not break
„ „	1 „	30 „	670 „	4·0 „	Not broken
Cement	2 years	30 „	230 „	6·4 „	„ „
„	2 „	30 „	200 „	6 4 „	Broken
Other cement	2 „	30 „	500 „	4·5 „	„
			560 „	4·5 „	„
			460 „	4·0 „	Not broken

VI. Tests of Mortars.

I have tested some specimens of a mortar of 1 : 3. The impressions are not so well defined as in neat tests, which is only natural, but are still perfectly discernable. The 25 mm ball seems to be preferable in this case to the 30 mm ball. The impressions should be further spaced from one another and further removed from the wall of the receptacle than with neat tests. The outcome is that, provided a somewhat more delicate mode of operation be applied, the hardness seems to be readily applicable also for mortar testing.

That would be a great step in advance. For it would enable us to conduct the tests under conditions, which would come much nearer the requirements of a practical examination, and to classify the products much better according to their real value.

The method could further be applied to the testing of sand mortars.

VII. Conclusion. Proposed rule.

From the just described experiments the conclusion may fairly be drawn that it will be possible henceforth, and is possible already, to make the hardness determination the basis of an ac-

ceptance test, if not of coefficients which can be considered as fixed in an invariable manner. It must be left to every engineer to see, how far he can, by his own experience, eliminate the least carefully manufactured products of the region in which he is stationed.

Leaving apart every theoretical consideration concerning the definition of stetting and the determination of the beginning and end of the period, the proposed rule is based upon the following two principles:

1. To guarantee the employer against the risk of having to regauge at the moment of application, because the setting had been to rapid.

2. To afford to him, in a minimum of time, by precise tests to be made at definite intervals, certain indications in the way in which the hardening proceeds, such that he can decide upon the definitive acceptance of materials supplied, without having to wait from 28 to 84 days for the results of tension tests, results, which irrespective of the long time required, do not present him with any guarantees of equivalent exactitude.

Working on neat pats, under the experimental conditions above described, with a ball normally of 30 mm, loaded with 15 kg, the times being counted from the moment of pouring out the gauge water, the following maximum coefficients of hardness have been observed after 3 hours and the minimum coefficients after 24 hours.

	Δ Maxim.	Δ Minimum 24 hrs.	3 days	7 days
Ordinary hydraulic lime	2	6	12	20
Lime very highly hydraulic . . .	2	8	15	27
Roman cement	2	35		
Natural slow-setting cement . . .				
Artificial Portland cement	2	42		
Slag cement	2	25		
Rapidly-setting cement[1])	2			

[1]) For the rapidly-setting cements the time of 3 hrs. is reduced to a quarter of an hour.

More prolonged experiments will, I hope, enable me, by adding the coefficients for 3 and for 7 days and particularly by working on mortars of 1 : 3 and 1 : 5, to demonstrate that these tests—joined to those of the invariability of the volume in the hot—will suffice to pronounce definitely on the acceptance of materials supplied.

In concluding I wish to express all my thanks to M. Henri Le Chatelier for the interest and kindness with which he has watched these experiments; they were carried out in his laboratory.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

X12

THE DEVELOPMENT OF THE SETTING OF ROMAN AND PORTLAND CEMENTS IN PASTE, IN MORTARS, AND IN CONCRETE.

(Report on Problem 33.)

By Prof. Dr. **Constant Zielinski**, Budapest.

(Translated from the Hungarian.)

The Third International Congress of the Association for Testing Materials, held in Budapesth in the year 1901, invited the Hungarian Association for Testing Materials to study the problem of the connexion existing between the strengths attainable in Roman and other cements, by the use of different quantities of water and different additions of sand and to communicate the results to the next International Congress, as also eventually to submit proposals in regard to a new standard test that should adapt itself better to the peculiarities of the Roman cements.

Conscious of the importance of the matter, the Hungarian Association for Testing Materials gladly accepted the invitation with which it had been honoured, and shortly after the Budapesth Congress of 1901 initiated a movement among the members of the Hungarian Society of Engineers and Architects, with a view to the constitution of a committee in which the public authorities, institutions, private firms and associations interested in the question should be adequately represented.

The Committee was fully alive to the great extent and expense of the experiments connected with such an investigation, and therefore, in order to secure the funds necessary for this

work of public interest, had recourse to the assistance of the public authorities, institutions, private firms and associations. The Hungarian Government was the first to set an encouraging example to contributors. Nor did the Hungarian public disappoint our expectations, for, within a short time, the estimated sum of 50,000 crowns (about 2000 guineas), required to cover the expenses of laboratory-equipment and experimenting, was collected by subscription. The Committee was formed and succeeded in securing Herr Kgl. ung. Hofrat Prof. Desider Nagy for the burdensome office of organiser. On the basis of the programme elaborated by Professor Nagy who worked out the comprehensive programme of tests in the most minute detail, the Committee was able to begin operations in the month of May, 1902, in a laboratory especially equipped for the purpose, and the work was continued uninterruptedly until 1905, under the personal leadership of the R. Engineer Josef Zhuk, attached to the Hungarian State Institute for Testing Materials.

The enormous labour involved in exercising control over the work of investigation was undertaken by the members of the Committee and distributed among them, so that upwards of 38.000 tests results were authenticated, checked, and duly recorded.

For the carrying out of the experiments, the Committee accepted the method initiated in 1901 by Dr. Zielinski, Professor in the Budapesth University of Technical Sciences, and with the collaboration of Mr. Jos. Zhuk were communicated by him to the Budapesth International Congress in a paper entitled "Comparative Methods of Testing Roman Cements".*)

The Committee based its resolution on the circumstance, that this method had established its claim of furnishing a means of accurately controlling the correctness of experiments carried out with different kinds of material.

In short, the process was deemed suitable for the purpose of investigating the law governing the setting in compact test samples at well as in samples described as not compact. The

*) See paper "Vergleichende Untersuchungen der Romanzemente und Prüfung ihrer Verwertung in der Praxis." ("Comparative methods of Testing Roman Cements and of controlling their application in practice"), by Const. Zielinski and Josef Zhuk, Budapesth Congress publications. 1901.

weight of which is calculable beforehand, and their correct preparation subsequently determinable by the help of the weighing balance.

Before the Committee arrived at this resolution however, it verified again, beyond all doubt, by a series of preliminary experiments undertaken for this purpose, that the weight of well-prepared bodies for testing purposes can be estimated beforehand, ander the supposition that the volume of the test sample the specific weights of the materials contained in it and the proportions borne by the materials to one another have been determined and are known beforehand. The Committee had then arrived at the conviction, that the task of carrying out researches with different materials, mixed in different proportions, could be acomplished on the basis of no other uniform method, and that no other method afforded such adequate means of controlling the experiments as this one, especially in the matter of the quality of samples submitted to test. It is beyond doubt then, that without regard being given to the two cardinal conditions of uniformity and control, no results adapted to purposes of comparative study are obtainable.

In other words, it may be asserted that, in working with materials mixed in a variety of proportions, none of the methods hitherto adopted would offer a uniform basis for characterizing conclusions, as does the method applied by the Committee. Neither the attainment of uniformity in the amount of mechanical labour applied in the preparing of the bodies to be tested — a uniformity prescribed by the usual standards for comparative tests — nor the previous prescription of average densities for the bodies to be tested regardless of the specific gravities of the materials contained in the mixture — a method advocated by Herr Frey (Luterbach) and supported by professor Schüle of Zürich — offers a uniform basis suitable for comparative research, or leads to characteristic deductions and justifiable results.

I. The Cements Tested.

The Hungarian Roman cements which are prepared from the lime-marl occurring in different parts of Hungary differ from one another very considerably in quality, so that, as can be seen from Table I below, the percentages of lime contained by them vary materially.

This difference in the percentage of lime is thoroughly characteristic for the products of the different factories. According to the experience which we have acquired during the last decades, the characteristic properties of our Roman cements rich-in-lime are, in practice, strikingly different from those of such cements as are poor-in-lime, although these latter, when submitted to the standard tests now usually employed, though not giving quite the same results, yet satisfy the requirements of these standands. In other words, it may be regarded as established, that the results of the standard tests do not show clearly, and do not characterize those properties of the different Roman cements, which are, in practice, of importance during the process of working-up.

Table 1.

Average Values of the Chemical Constituents of the Roman Cements tested.

Description	Silicates Soluble	Silicates Insoluble	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Alkalis	Total
Roman cement rich-in-lime	20·40	2·70	8·73	4·24	58·86	1·55	2·38	1·14	100
Roman cement poor-in-lime	23·90	14·49	8·17	3·64	45·22	2·09	0·72	1·77	100

Table 2.

Chemical Constituents of the Portland Cements investigated.

Description	Silicates Soluble	Silicates Insoluble	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Alkalis	Total
Portland cement	19·12	0·36	8·32	3·72	63·24	1·34	3·17	0·73	100

Accordingly, the Committee employed in its researches characteristic Roman cements rich-in-lime and poor-in-lime as

derived from different factories, and also, with a view to the establishment of the fact that the process followed is suitable for ascertaining the important properties of other hydraulic cements have likewise included the testing of Portland cements in their programme.

The average results obtained from the standard tests applied to the Roman cements prepared with Vienna standard sand are given in Table III, and the results for the standard tests of the Portland cement with Vienna standard sand in Table IV.

II. Other Constituents submitted to Test.

Beyond the investigation of the influence exercised on the attainable strength of the cements by changes in the quantity of water used in working them up, the inquiry was extended to the effects arising from variations both in the quantity and in the quality of the sand and gravel contained in mortars and concretes.

Accordingly, in addition to the Vienna standard sand used in examining cements by the so-called standard tests, the Committee included in its researches river-sands (especially the Danube sand so extensively used in Hungary) a characteristic kind of quarry-sand used in this country, and crushed sand obtained from the sand-stone of the Carpathians.

In the course of the inquiry into the strength attainable in concretes, the Committee extended its investigations to river gravel and to gravel obtained by crushing basalt, lime-stone and brick.

In the establishment of the results obtainable in mortars and concretes with the different materials enumerated, the Committee did not consider that it had exhausted its task, but extended the research for the purpose of solving whatever questions it judged to be of public interest. Thus, for example, it widened the scope of the inquiry by examining into the influence exercised on the strength attainable in hydraulic cements by the size of sand grains, the uniformity or non-uniformity of the grains of the various sands which in other respects bear the same character, and by other similar matters to be referred to later.

A. Kinds of sand.

The series of experiments described below in detail, were made on the following kinds of sand:

1. Uniform sand.

Results of Standard Test with Roman Cements.

Table 3.

Description	Liter-weights kgs.			Specific Gravity	Fineness of Grinding				Setting-Time			Constancy of Volume of cakes after 28 days		Tensile Strength kg per cm²				Compressive Strength kg per cm²		
	Loose	Riddled in	Firmly shaken-down		Residue on the 900% sieve	Residue on the 2500% sieve	passed through the 2500% sieve	Total	% Water used	Beginning (in minut.)	End (in minut.)	in air	in Water	% Water used	Apparent Spec. Grav.	after 7 days	after 28 days	% Water used	Apparent Spec. Grav.	after 28 days
Roman Cement rich-in-lime .	0·620	0·665	1 093	2·88	10·8	9·0	80·2	100	55·5	17	66	withstood		10·70	2·25	14·3	20·6	10·90	2·24	139·7
Roman Cement poor-in-lime .	0·800	0·868	1·423	2·84	4·6	16·6	78·8	100	41·5	16	102	„		9·85	2·29	6·2	16·0	9·25	2·86	97·8

Results of Standard Test with Portland Cements.

Table 4.

Description	Liter-weights kgs.			Specific Gravity	Fineness of Grinding				Setting-Time			Constancy of Volume			Tensile Strength kg per cm²				Compressive Strength kg per cm²		
	Loose	Riddled in	Firmly shaken-down		Residue on the 900% sieve	Residue on the 2500% sieve	passed through the 2500% sieve	Total	% Water used	Beginning (in minut.)	End (in minut.)	of cakes after 28 days in air	of cakes after 28 days in Water	Ball Boiling Test	% Water used	Apparent Spec. Grav.	after 7 days	after 28 days	% Water used	Apparent Spec. Grav.	after 28 days
Portland Cement	1·076	1·136	1·700	3·07	3·3	16·7	80·0	100	31·0	135	420	withstood			7·5	—	21·5	26·4	7·4	—	315·8

That sand is called "uniform" the grains of which remain on the sieve containing either 64 or 144 meshes to the square centimetre. Uniform sand in this sense is prepared from:

a) Vienna standard sand,

b) River sand.

2. Mixed sand.

In the description of our experiments the following are briefly named mixed sand:

a) Ordinary river sand of all sizes of grain which passes through a sieve with meshes of 5 millimetres,

b) sand obtained by the crushing of Carpathian sand-stone and passed through the 5 millimetre sieve.

3. Fine sand.

In what follows, fine sand is to be understood as that which falls through a sieve containing 144 meshes to the square centimetre. On our experiments the fine saud is more closely designated under the name of the sand from which it is riddled. Thus we distinguish:

a) Vienna fine sand,

b) Fine river sand,

c) Fine quarry sand.

B. Kinds of Gravel.

The kinds of gravel and the size of grains used in making concrete are as follows:

1. Smooth gravel.

By this we understood river gravel with rounded grains, and such that it is mixed in the proportion of two parts from the 20 mm sieve and one part from the 40 mm sieve.

2. Rough gravel.

a) Lime-stone gravel,

b) Basalt gravel,

c) Broken brick,

crushed small from rough stone or brick, and mixed in the proportion of one part from the 20 mm sieve and two parts from the 50 mm sieve.

III. The Method of Experiment.

As was mentioned in the introduction, the Committee, based it studies and the comparative experiments connected with them on compact and porous test-samples such as would yield comparable results, because their uniformity and composition could be checked and verified by simple means. The grivities of a well-made sample for testing purposes, whether compact or porous, can be calculated in advance (in accordance with the formulae given below) provided the specific weights of the materials to be employed in constructing such test-sample, the relative quantities of the constituent materials, and the cubical contents of the sample are known. Consequently the construction of the test-sample can be checked entirely without consideration of the labour applied, or of any single arbitrary condition simply by weighing, and its excellence, that is, its suitability for comparison in this investigation, can be definitely established.

It can be easily verified that, if the specific gravities of the cement, sand, gravel, and water be respectively $\varkappa$, β, γ and 1, and if further the weight of each constituent be expressed as a proportionate part of the weight of the cement — the weight of cement used up being taken as the unit — then the composition of the test-sample is completely determined by the following factors, viz: the weight of the cement 1, the weight of sand p, the weight of gravel q, and the weight of water r. In order to establish a relation between the weight and volume of samples which are not compact, that is, samples designated as porous in the following pages, we must in addition to the specific weights and the quantities of the constituent materials, introduce another factor, which we may conceive as an "interstice" factor. This so-called interstice factor must be understood to express the minimum sum of physically possible empty spaces or interstices in the volume of the solid, when in the loose condition, as for example, in the volume of the sand or gravel.

The interstice factors may be determined either directly by measurement with the volumenometer or indirectly by a calculation, in which the ratio of the specific gravity to the maximum apparent specific gravity is subtracted from unity.

The work of calculating will be facilitated, if we group and tabulate the numerical values of the above-mentioned factors and the ratios occurring in the course of the calculations, as follows:

		Cement	Sand	Gravel	Water
1	Specific Gravities	α	β	γ	1
2	Maxima of Apparent Specific Gravities .	a*	b	c	1
3	Factors for proportions of materials mixed	1	p	q	r
4	Reciprocals of Specific Gravities . . .	$\frac{1}{\alpha}$	$\frac{1}{\beta}$	$\frac{1}{\gamma}$	r
5	Ratio of Spec. Grav. to Apparent Spec. grav.	$\frac{a}{\alpha}$	$\frac{b}{\beta}$	$\frac{c}{\gamma}$	1
6	Interstice-Factors	$1-\frac{a}{\alpha}$	$1-\frac{a}{\beta}$	$1-\frac{c}{\gamma}$	0
7	Ratio of the Proportion Factors to the Specific Gravities	$\frac{1}{\alpha}$	$\frac{p}{\beta}$	$\frac{q}{\gamma}$	r
8	Ratio of the Proportion Factors to the Apparent Specific Gravities	1	$\frac{p}{b}$	$\frac{q}{c}$	r

With these data the weights may be calculated from the following formulae:

A. The Weights of the Pastes.

1. If V be the volume of the compact paste, the weight

$$G = V \cdot \frac{1 + r}{\frac{1}{\alpha} + r} \qquad (A1)$$

The condition of compactness in the case of paste, is

$$r > \frac{1}{a} - \frac{1}{\alpha}^{**}$$

2. If V be the volume of the porous paste, the weight

$$G = V \cdot \frac{1 + r}{\frac{1}{a}} \qquad (A2)$$

The paste is porous, if

$$r < \frac{1}{a} - \frac{1}{\alpha}^{**}$$

Note. The Committee did not determine either the maximum Apparent Specific Gravity for cement or its interstice-factor, and consequently the condition ** and the formula A2) for the weight of porous paste are for the present, pending the determination of a*, only imaginary values.

B. Weights of Mortars.

1. If V be the volume of the compact mortar the weight

$$G = V \cdot \frac{1 + p + r}{\frac{1}{\alpha} + \frac{p}{\beta} + r} \qquad \text{(B 1)}$$

The mortar is compact, if the space is completely occupied by water and cement, and the sum of the interstices between the grains of sand is a minimum. This is the case, if

$$r > \frac{p}{b}\left(1 - \frac{b}{\beta}\right) - \frac{1}{\alpha}$$

2. If V be the volume of porous mortar, the weight

$$G = V \cdot \frac{1 + p + r}{\frac{p}{b}} \qquad \text{(B2)}$$

The mortar is porous, if the minimum sum of the interstices between the grains of sand is not occupied by water and cement. This is the case, if

$$r > \frac{p}{b}\left(1 - \frac{b}{\beta}\right) - \frac{1}{\alpha}$$

Weight of Concrete.

1. The weight G of compact concrete of Volume V is given by

$$G = V \cdot \frac{1 + p + q + r}{\frac{1}{\alpha} + \frac{p}{\beta} + \frac{q}{r} + r} \qquad \text{(C1)}$$

The concrete is compact, if:

$$p > b\left(1 - \frac{c}{\gamma}\right)\frac{q}{c} \text{ and } r > \frac{p}{b}\left(1 - \frac{b}{\beta}\right) - \frac{1}{\alpha}$$

or if:

$$p < b\left(1 - \frac{c}{\gamma}\right)\frac{q}{c}, \text{ but } r > \frac{q}{c}\left(1 - \frac{c}{\gamma}\right) - \left(\frac{1}{\alpha} + \frac{p}{\beta}\right)$$

In both cases the concrete is compact if the ration of combination and the water used in the process satisfy the criterion; the interstices between the grains of gravel and sand are then completely filled up by cement and water.

2. If V be the volume of concrete which is porous, that s to say, not compact, the weight

$$G = V. \frac{1 + p + q + r}{\frac{q}{c}} \qquad \text{(C 2)}$$

if: $p < b\left(1 - \frac{c}{\gamma}\right)\frac{p}{c}$ and $r < \frac{q}{c}\left(1 - \frac{c}{\gamma}\right) - \left(\frac{1}{\alpha} + \frac{p}{\beta}\right)$

or

$$G = V. \frac{1 + p + q + r}{\frac{p}{b} + \frac{q}{\gamma}} \qquad \text{(C 3)}$$

if: $p > b\left(1 - \frac{c}{\gamma}\right)\frac{q}{c}$, but $r < \frac{p}{b}\left(1 - \frac{b}{\beta}\right) - \frac{1}{\alpha}$

It must here be observed, that if the quantity of water used in mixing be in excess of the cement's absorbing capacity, that is to say, if it exceed the quantity which the cement is capable of setting then of course a smaller quantity of water comes into the set cement than was used in the mixing; in order, then, that in this case the weight of the prepared sample may be calculable in advance the quantity of water r used in mixing must be corrected in accordance with the actual facts.

The correction of r in our experiments was made in this way. After the setting process in the sample was completed, the water not set was carefully measured and deducted from the total quantity used in mixing, and thus the corrected value of r determined. The weight of the test sample with this corrected value of r was exactly calculated.

The results of subsequent weighing completely verified the correctness of the process described.

With this we have exhausted the eventualities which can arise in the course of the preparation of the test samples.

It may be seen from the foregoing, that, whatever may be the components — the mixing proportions — of the sample to be constructed for the test, the weight of the heaviest, most compact sample corresponping with the mixing proportions, that is with the apparent specific gravity can always be determined in advance. It is necessary then, in the preparation of the sample to bring it to the weight required by the calculation by the aid of suitable and adequate mechanical means, if we wish

to ensure with the same mixing proportions, the attainment of samples of like structure which can be qualitatively compared.

The nature and the amount of mechanical labour applied to the preparation of the test sample is from this stand-point a perfectly indifferent matter. In the interest of simplicity in practice, however, it is important for us to aim at obtaining the weight of the sample (calculated in advance) with the simplest instruments and the easiest and most efficacious manipulation.

In the course of the work, the Committee arrived at the conviction that it is unnecessary to prescribe a uniform method of procedure for the preparation of test samples; for if the mode of operation be changed or the amount or duration of the mechanical labour applied in the manipulation undergo a variation, but at the same time the attainment in the prepared sample of the weight — or what is the same thing, of the compactness — be strictly exacted, the divergencies of the strengths attained under similar circumstances after the same lapse of time have been less considerably less than those always perceptible in the case of the ordinary tests conducted according to a rigidly-prescribed process and with a strictly-prescribed uniform expenditure of mechanical labour.

Why the Committee chose this method of carrying out its experiments, may be seen from this preliminary explanation.

From the experiments it must be regarded as completely demonstrated that, with this process, we can in fact prepare samples similar in structure and suitable for comparison, independently of the kind and quantity of the mechanical labour expended.

This fact the Committee regards as established beyond dispute by the large number of experiments carried out during a number of years, and therefore, relying on the experience acquired, begs to recommend the process in question for adoption in comparative experiments, that is its general acceptance as a basis of standard tests.

For this purpose the Hungarian Association for Testing Materials requests the Congress to refer the question in its present form to a Committee of the International Association for decision and a declaration of its opinion as to the nature of the process and as to whether it is suitable for use in the making of standard tests of strength and worthy of universal ordainment.

IV. Scope of the Research.

After we have eschaustively discussed the method, it seems desirable to indicate in a few words the principal points in the series of experiments performed with the different kinds of cement.

1. In the first place, all the characteristic properties of the cements investigated by us were determined in accordance with the standards now in use in order that we might inform ourselves as to their quality in the ordinary manner.

2. Afterwards we considered the question as to the position taken by the cement as an independent binding material with reference to the proportion of water applied, what influence the total quantity of water, chemically and physically bound in the course of working up the cement, exercised on the process of setting, what phenomena accompanied the progress of setting in air and under water respectively, and what law the setting fallows in relation to the increase in the time of its duration.

The test-samples for these experiments were, of course, prepared with cement and water and designated "pastes" comformably with the degree of consistency they exhibited in being worked up.

3. Having ascertained the independent binding-capacity of the cement, we desired to establish how the binding capacity manifests itself in mortars prepared with sand from different sources and with grains of different kinds and sizes. The investigation was especially extended to the strengh attainable with mortars prepared with like paste and with like sand, mixed in varying proportions, in order to obtain a picture of the influence exercised on the setting of the mortar by its degree of strength, the amount of paste contained in it and its porosity, and, further, to observe how the development of such mortars progressed in air and under water.

4. Finally the binding-power of cement was investigated in concretes prepared with mortar of known quality and with different kinds of gravel, mixed in different proportions. The Committee likewise devoted special attention to the effect of the degrees of fatness and porosity in concretes.

It can be seen from this brief description, how extended was the series of experiments carried out with each particular cement, and if we take into consideration the circumstance that a like

extended series of experiments was performed with each one of a series of cements, we can form on idea of the enormous amount of work which the Committee devoted to this far-reaching and thorough investigation for the establishment of a basis on which to judge of the quality of cements.

The results we have obtained are described in detail below and illustrated by diagrams.

A. Diagram of the Pastes.

In the case of pastes, we have as independent variables only r, the proportion of water added, as a quotient of the weight of the cement, and t, the time of hardening, expressed in terms of days or weeks.

It follows from the nature of the problem that we regard as dependent variable σ, the strength indicated by the sample subjected to the breaking-test. This is expressed in the usual way in kgs. per cm^2.

In the case of the pastes we have shown, by means of a curve, the functions:

1. $\sigma = f(r)$ for the case in which t is constant.
2. $\sigma = F(t)$ „ „ „ „ „ r „ „

B. Diagrams of the Mortars.

In the case of mortars, we have as independent variables r and t,and in addition p, the proportion of sand added, a quotient of the weight of the cement. Therefore for results obtained with mortars we can shew the results in the form of curves:

1. $\sigma = f(r)$, when p is constant and t constant.
2. $\sigma = F(t)$ „ p „ „ „ r „
3. $\sigma = \varphi(p)$ „ r „ „ „ t „

C. Diagram of the Concrete.

In the case of concrete we have a fourth independent variable in addition to the foregoing ones, r, p and t, which is q, the proportion of gravel employed in the mixture.

It is therefore possible to illustrate the hardening of the concrete by means of fair curves, only if the following conditions are satisfied:

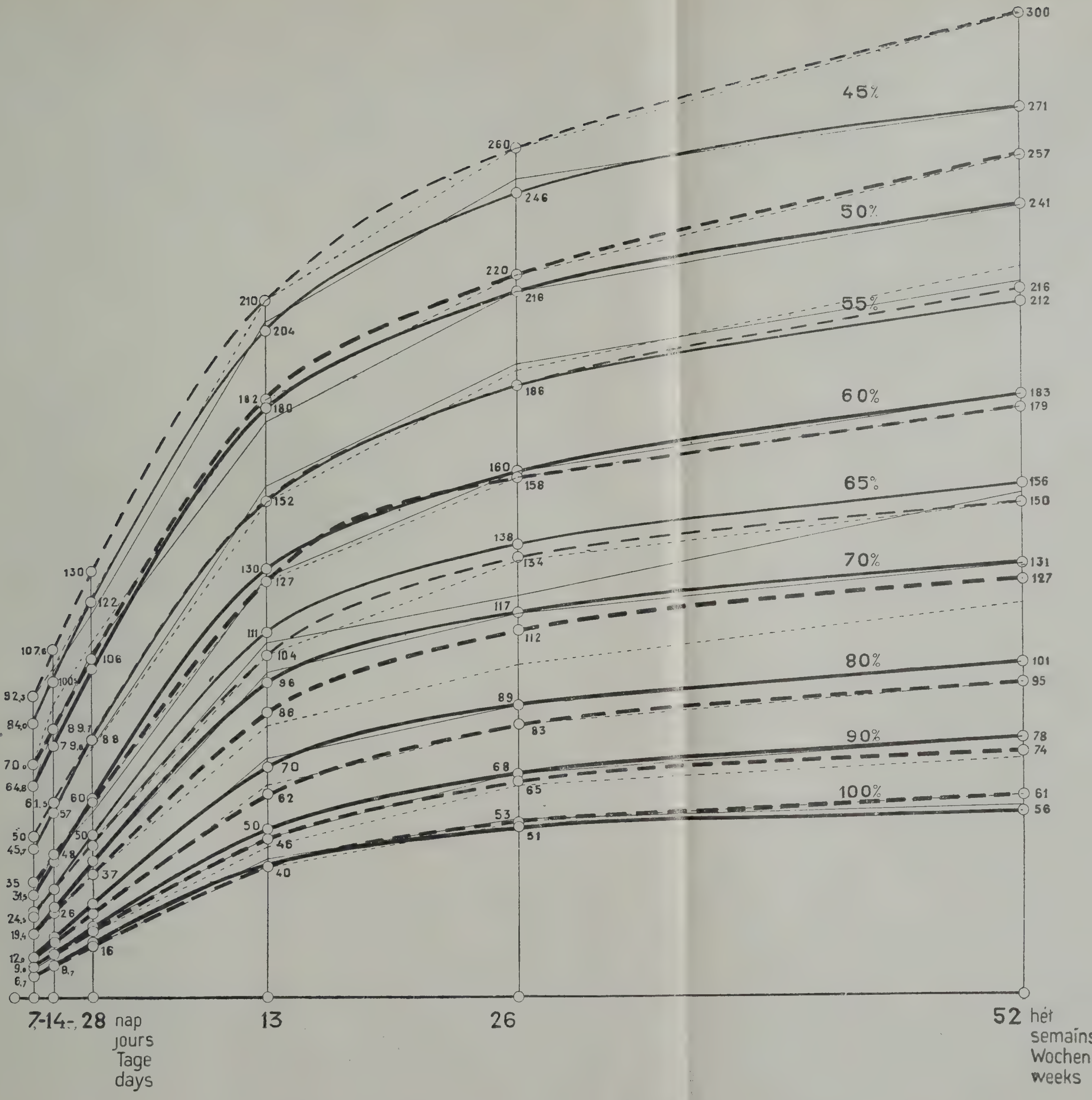


Diagram VI. Time Lines for Roman Cements rich-in-lime.

$\sigma = F(t)$ kg per cm^2.

Cement-Pastes ————

Mortars — — — — — —

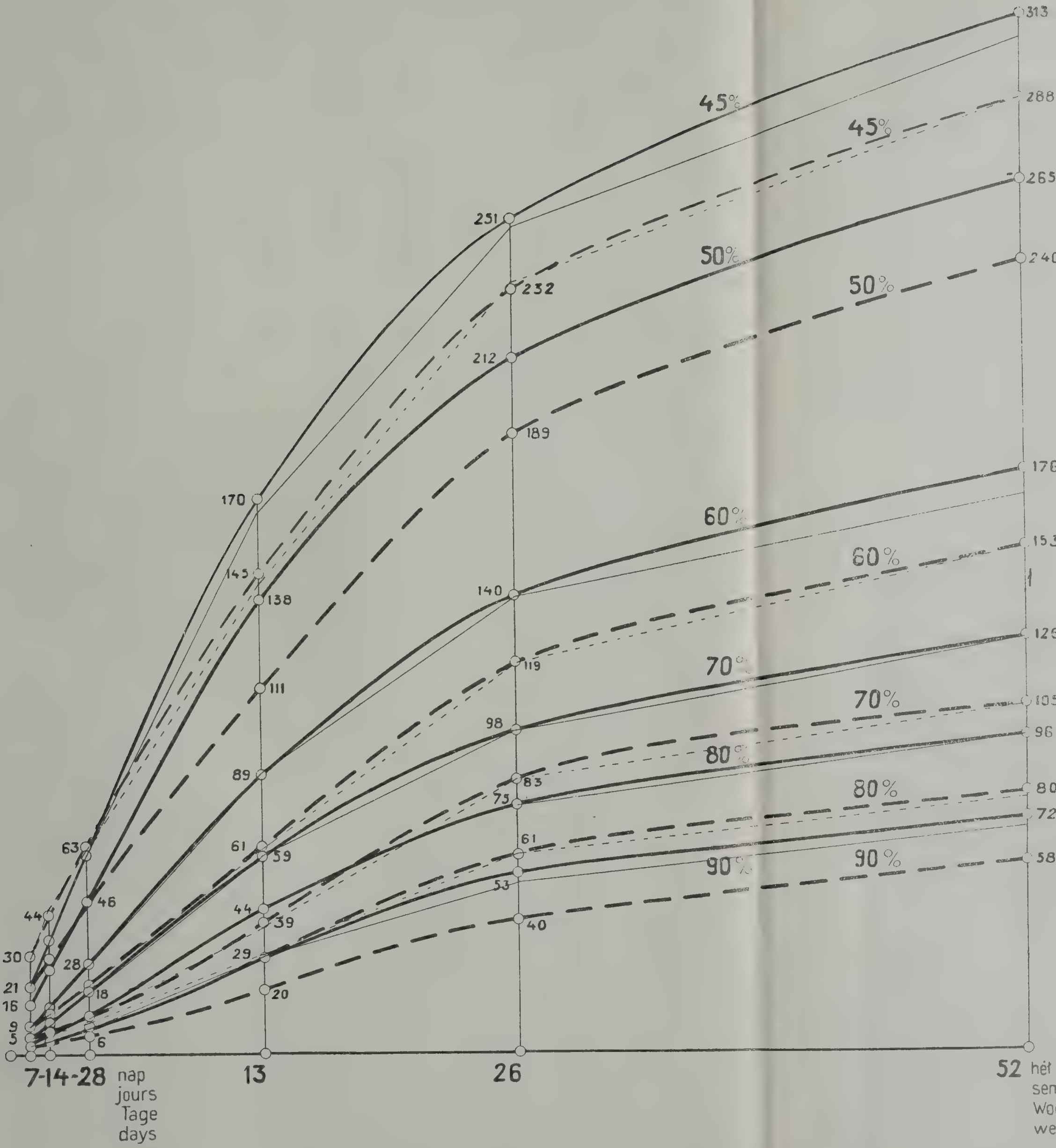


Diagram VII. Time Lines for Roman Cements poor-in-lime.

$\sigma = F(t)$ kg per cm².

Cement-Pastes ————————

Mortars — — — — — — — —

1. $\sigma = f(r)$, when q, p and t are constant
2. $\sigma = F(t)$, „ q, p „ r „ „
3. $\sigma = \varphi(p)$, „ q, t „ r „ „
4. $\sigma = \psi(q)$, „ p, t „ r „ „

The data and results of our experiments are recorded and collected in 108 tables in such a manner, that we can set off all the above given functions in the form of curves, that is, we can obtain a clear view of all questions which have to be elucidated.

We may now pass to a consideration of the conclusions to be deduced from the results of the experiments.

V. The Influence of the Water on the Process of Hardening.

The Committee, in accomplishing the task it had undertaken, carried out two similar series of experiments, one with Roman cement rich-in-lime and the other with Roman cement poor-in-lime.

In Diagram I relating to these series of experiments we show the strengths attainable with the Roman cements rich-in-lime, when the value of r, representing the numerical ratio of the weight of water to the weight of cement is successively taken as: 0·45, 0·5, 0·55, 0·6, 0·65, 0·7, 0·8, 0·9 and 1.

Diagram II shows the strengths attained with Roman cements poor-in-lime when we give to r the following values successively: 0·45, 0·5, 0·6, 0·7, 0·8 and 0·9.

With Roman cements poor-in-lime we reached the limiting point of working-up at $r = 0·9$; in the case of Roman cements rich-in-lime the cement can still be worked when r exceeds 1; but the liquidity is then so great, that the results would be of no practical or theoretical value, and therefore, even in the case of our Roman cements rich-of-lime, we did not extend the scope of the experiments beyond $r = 1$.

In Diagrams I and II the ascertained strengths are set off in curves from the equation $\sigma = f(r)$, r being the abscissa and σ the corresponding ordinate.

In the diagrams the independent binding-capacity of our Roman cements is marked with the strengths attainable with pastes, and their mortar-forming strengths are shown with a mixing proportion of cement to Vienna standard sand of 1 : 3.

It must be observed that the results given in Diagrams I and II, as well as in the others giving our collected data, are those

obtained from processes of setting under water. The restricted scope of the report prevents us from communicating the similar data which we have obtained for the setting in air.

We have determined the development of the strength after 7, 14 and 28 days and after 13, 26 and 52 weeks respectively; it therefore becomes possible to set off the function $\sigma = f(r)$ for paste and for mortar of 1 : 3 in the form of six curves for each. For example the 7-day line discloses a diminution in the strengths developed during 7 days, with increasing additions. The full line gives a picture of the strength reached with pastes and the dotted line that reached with mortar made with Vienna standard sand in the proportion 1 : 3.

A. Investigation of the Water Lines.

In the following pages the diagrams will, for the sake of brevity, always be named according to the nature of the abscissae. Thus the curves given in Diagrams I and II will henceforth be styled the water lines. The letters m, d, r denote the Roman cements rich-in-lime, and m, sz, r the Roman cements poor-in-lime.

1. It may be seen from Diagrams I and II that the binding-capacity of Roman cements rapidly diminishes with the increase in the quantity of water used in the working-up process. This is confirmed by Diagrams III and IV. The same statement applies also to Portland cements and therefore to cements in general.

2. It may further be seen, that the diminishing effect of the quantity of water on the strength attainable is a permanent one; for a rapid diminution has been determined at every stage of the development of the setting process. This is confirmed by the 7, 14 and 28 days lines and the 13, 26 and 52 weeks lines.

3. The unfavourable effect of the quantity of water in pastes and mortars was manifested also in the case of concretes, as is demonstrated by the experiments we have carried out with these.

From this it can be concluded that, apart from the quality of cements, the strength attainable with them is, in the first place and to the greatest extent, influenced by the quantity of water added in the working-up process.

The p corresponding with the proportional addition of water usual in building operations is nearly equal to the average of

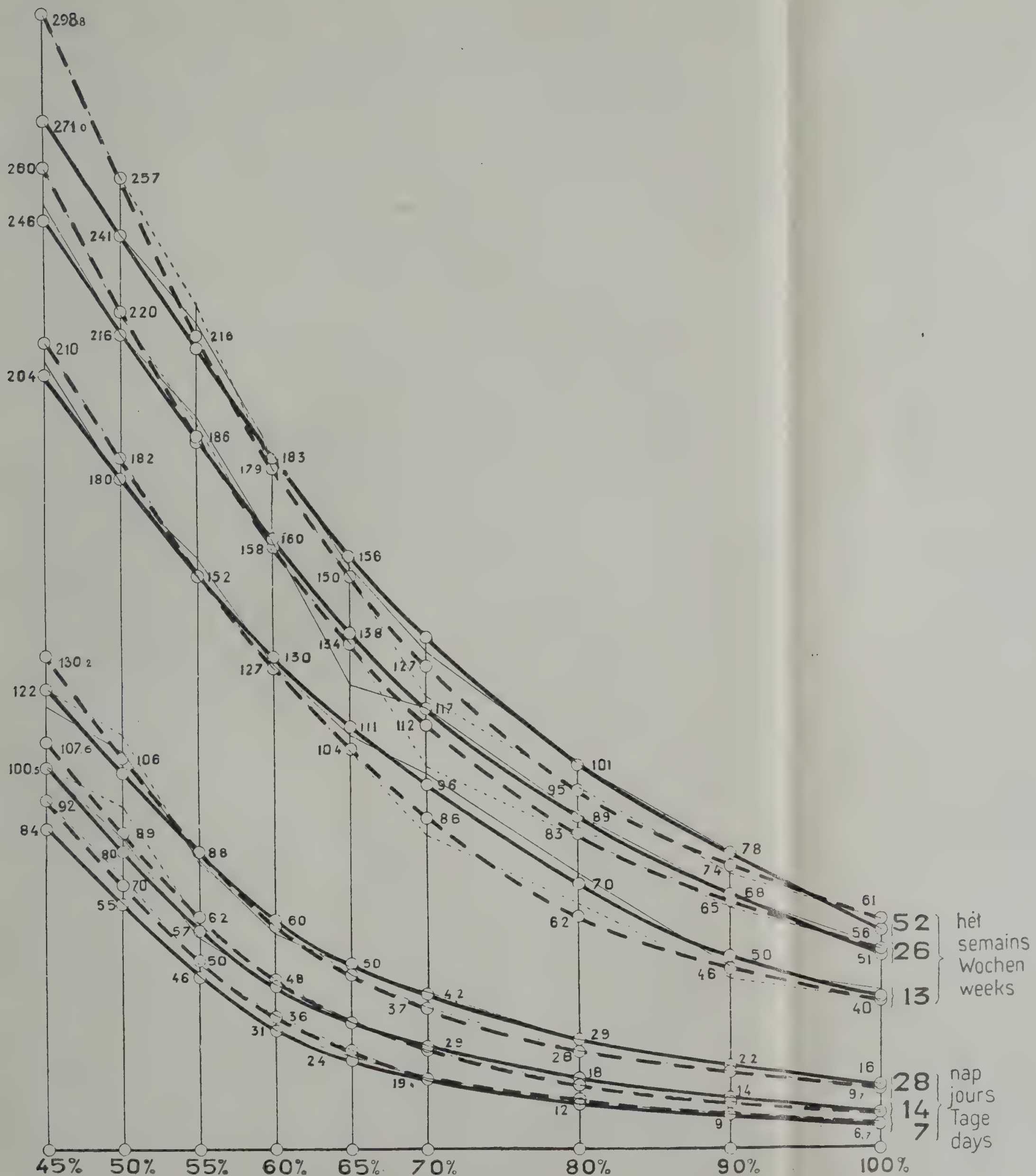


Diagram I. Water Lines for Roman Cements rich-in-lime.
$\sigma = f(r)$ kg per cm².
Cement-Pastes ————
Mortars — — — — — — —

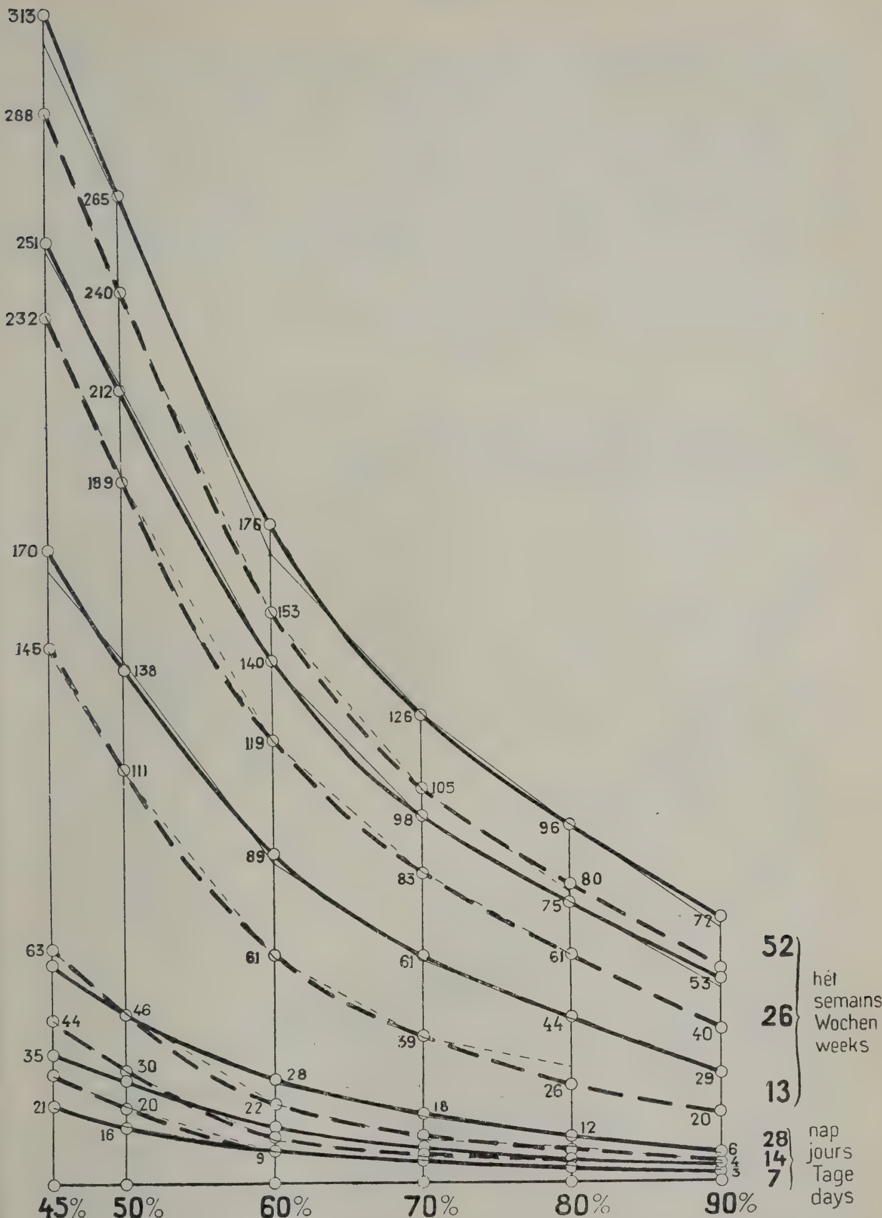


Diagram II. Water Lines for Roman Cements poor-in-lime.

$\sigma = f(r)$ kg per cm².

Cement-Pastes ————————

Mortars — — — — — — — —

this value for our series of experiments. If, at about the average values of p, we increase the water by 0·1, then we can assert generally, that the strength attainable diminishes by 0·3.

From the water lines for pastes and mortars, we can deduce the conception and law of the "value numbers".

Under the expression "value number" we understand the weight of cement corresponding to the unit of strength.

Let $\varkappa$ denote the value number, then

$$\varkappa = \frac{c}{\sigma}$$

where c is the weight of the cement contained in the test sample and σ is the measurement of the strength.

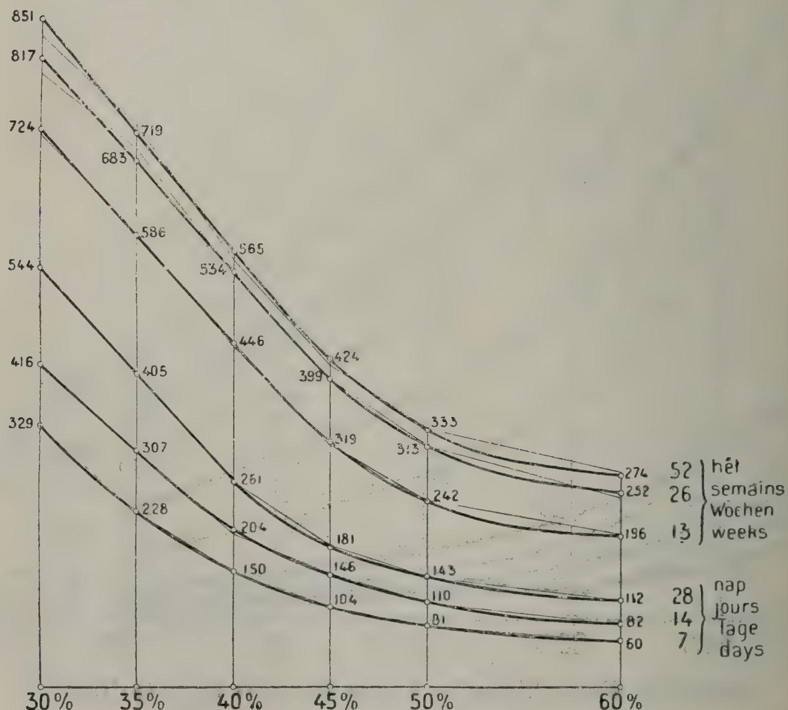


Diagram III. Water Lines for Portland Cement-Pastes.
$\sigma = f(r)$ kg per cm².

As c is a function of r, and likewise σ is a function of r when t is constant, it follows that, if t is constant, ϰ is also a function of r, that is, may be expressed

$$\varkappa = \psi(r).$$

To arrive at the form of ψ we calculated the cement-weight belonging to every σ by means of the known formulae.

For pastes:

$$c = V \cdot \frac{1}{\frac{1}{\alpha} + r}$$

For compact mortars:

$$c = V \cdot \frac{1}{\frac{1}{\alpha} + \frac{p}{\beta} + r}$$

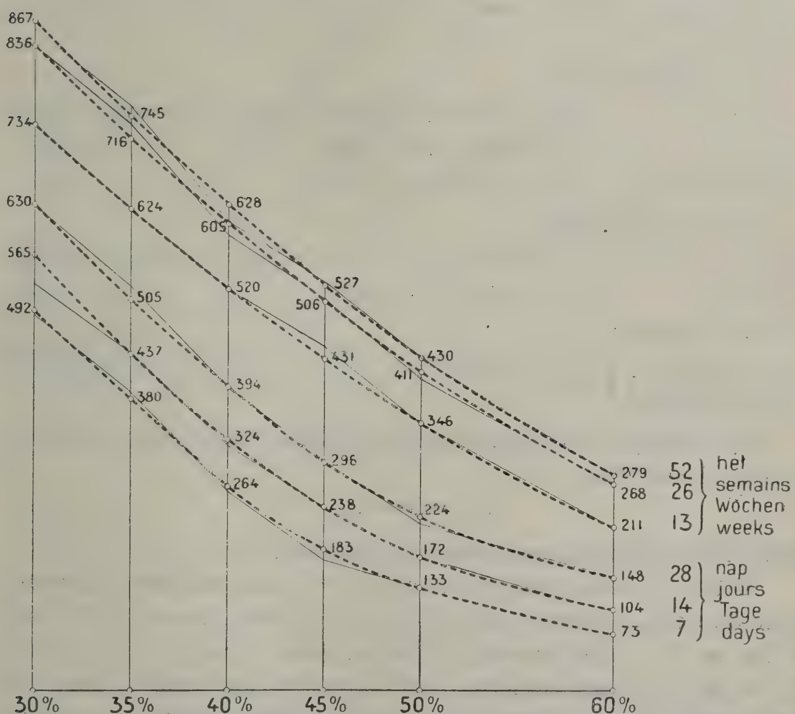


Diagram IV. Water Lines for Portland Cement Mortars.
$\sigma = f(r)$ kg per cm^2.

For porous mortars:

$$c = V \cdot \frac{1}{\frac{p}{b}}$$

We see that with α, p and t constant, that is, with given weight of cement, mixing proportion and time of setting, $\varkappa$ depends more on r.

Calculating the values for r and $\varkappa$ and at the transition $r = o$ referring them to rectangular coordinates, we can determine by means of Diagram III that

$$\varkappa = \psi (r)$$

represents a line, for pastes, mortars and concretes alike.

For example, we shew in Diagram V the regularity of $\varkappa$, which can be determined from the data of the 28 day water lines corresponding with the results obtained with the 353·5 cm^3 test-samples.

For pastes with:

M. d. r	$\varkappa = 0{\cdot}216\,r - 6{\cdot}6$;	direction tangent $= 0{\cdot}216$
M. sz. r	$\varkappa = 0{\cdot}44\,r - 12$;	„ „ $= 0{\cdot}44$
Portland cement .	$\varkappa = 0{\cdot}08\,r - 1{\cdot}2$;	„ „ $= 0{\cdot}08$

For mortars with:

M. d. r	$\varkappa = 0{\cdot}142\,r - 5{\cdot}6$;	direction tangent $= 0{\cdot}142$
M. sz. r	$\varkappa = 0{\cdot}4\,r - 14{\cdot}2$;	„ „ $= 0{\cdot}364$
Portland cement with river- (Danube) sand .	$\varkappa = 0{\cdot}028\,r - 0{\cdot}6$;	„ „ $= 0{\cdot}028$

According to our experience, therefore, the following formula in general satisfies $\varkappa$:

$$\varkappa = n \cdot r - m,$$

where n is the direction tangent of the line.

From the examples given above we can see that the value of the direction-tangent factor for m. sz. r is always about double that of the m. d. r direction-tangen factor, from which it follows that the m. sz. r. value-coefficient line is nearer the vertical than the corresponding m. d. r line. In the case of Roman cements, however, this line is out of all proportion nearer the vertical than in that of the Portland cements.

In general it can be established, that the cement weight corresponding with the unit of strength increases with the quantity of water used in the mixture. The proportion coefficients the value-coefficients differ considerably for the different kinds of cements. Among the cements which formed the object of our investigation, the greatest coefficient was at its maximum in the case of the weakest cement, the m. sz. r, and at its minimum in that of the strongest cement examined, the Portland cement.

It can be regarded as a rule, that the goodness of the cement stands in an inverse relation to the value-coefficient of the latter thus defined.

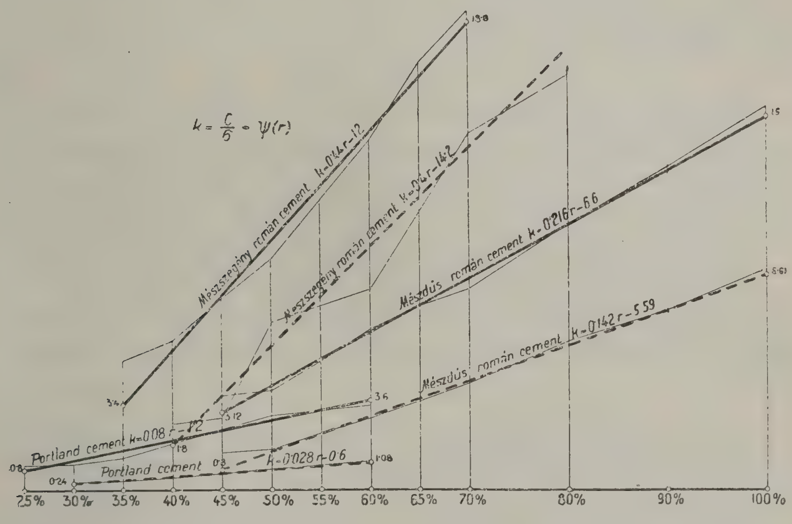


Diagram V. Value-Factor Lines for Roman and Portland Cements.

Cement-Pastes ——————

Mortars — — — — — — —

We must regard as highly important the determination of the circumstance that

$$\varkappa = \frac{c}{\sigma} = \psi \ (r)$$

represents a line for any cement, when p and t are identical; for this fact opens to us the way for the drawing conclusions relative to the total attainable strengths for any cement, where p and t remain unchanged; we need only make two experiments, with

two values of r lying as far apart as possible, that is with r standing as near as possible to its limiting values. In the case of mortars it is most appropriate for this purpose to choose for the lower value of r:

$$r = \frac{p}{b}\left(1 - \frac{b}{\beta}\right) - \frac{1}{\alpha}$$

and for the higher value, if possible, the cements capacity for absorbing water.

If in this manner we have obtained two separate connected values of r and σ, for some particular time of hardening and proportion of sand, we can calculate the two unknown quantities m and n of the equation

$$\varkappa = n.r - m$$

and thereupon the $\varkappa$, corresponding to any arbitrary quantity of water r, and then, the c being calculable from the formulae c given above, σ can also be calculated from the equation $\sigma = \frac{c}{\varkappa}$.

Thus we have indicated the way in which the total results of a whole series of experiments can be calculated in advance on the basis of two experiments made. We beg therefore to call the special attention of the Congress to this result.

It must still be remarked, however, that we have extended our investigations in order to ascertain whether with identical materials, mixing-proportions and time-of-hardening, a deviation does not appear in σ, that is, in the ultimate strength per square centimetre, when the volume V of the sample tested undergoes a change.

For this purpose, we completed a series of experiments with cubes of 7·07 cm, 15 cm and 30 cm in length and, as is demonstrated by the data given in Table 5 below, we found that the strength per square centimetre diminished as the size of the cube is increased. In our concrete-tests we found that the fall in the strength of cubes which have a greater length than 30 cm is scarcely perceptible, for the tested samples of 50 cm in length gave results sufficiently in accord with those of samples 30 cm in length.

Table 5.

Comparison of Resistances in Concrete Sample-Cubes of Different Lengths of Side after 28 Days.

Description	Mixing-Proportion by weight	Length of Earth-Moist Test samples of Concrete: 7*) cm	15 cm	30 cm	50 cm	Length of plastic Concrete Bodies: 7*) cm	15 cm	30 cm	50 cm
		strength in kg per cm² after 28 days				strength in kg per cm² after 28 days			
Roman cement rich-in-lime . .	1 : 4 : 4	67·9	33·4	32·4	31·3	43·0	21·0	18·1	17·2
Portland cement .	1 : 3 : 3	291·8	156·6	149·0	142·7	144·5	105·4	89·5	89·6

Hence the value factors which are important in practice, that is to say, those which we can employ for comparing the prices and values of particular cements, will have to be determined only from the test-results obtained with large samples

We shall not discuss the method of comparing prices and values in further detail, but wish to continue the analysis of the properties of cements on the basis of the results of our setting-experiments.

B. Investigation of the Time-Lines.

On the basis of the data which appear in the water-lines, we can draw the time-lines, only we must refer the times to the abscissae and the strengths to the ordinates, and we must connect by a continuous line the results obtained with samples prepared with the same r. The striking difference which we can remark between the m. d. r. and m. sz. r. water-lines, especially after periods of setting of 7, 14 and 28 days, a difference which after 13, 26 weeks diminishes and after 52 weeks of setting (which we have introduced into our series of experiments) can be said to cease completely is explained better and more clearly by the time-lines, $\sigma = f(t)$, which we give for m. d. r. in Diagram VI, for m. sz. r. in Diagram VII, and for portland cement pastes and

*) The small concrete-samples were prepared with smaller gravel than the others.

mortars in Diagrams VIII and IX respectively. As mentioned above, the same data appear in these diagrams as in Diagrams I and II; only here the development of strength with regard to the progress of the time of hardening is more clearly exhibited.

The time-lines shown in the four diagrams offer, however, only a general view of the development of the strength with the advance of the time occupied in the process.

According to these it appears, as if the course of the strength would follow the same law in the characteristically differing Roman cements, that is, in m. d. r. and m. sz. r.

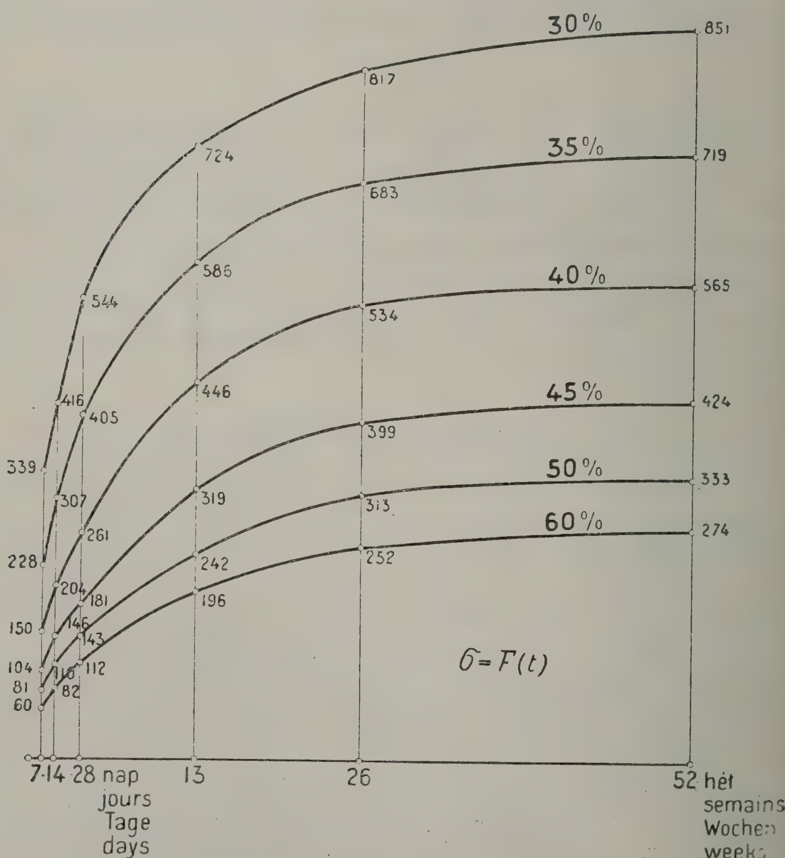


Diagram VIII. Time Lines for Portland Cement-Pastes.

The course of strength in the two kindsof cement, however, follows materially different laws during the time of most importance for practical purposes, i. e. the initial period comprising the first weeks following the application of the cement in building.

It is necessary therefore in the first instance to place the general picture in its right light. We shall consider first the beginning of the course of setting with Diagrams X and XI, where the m. sr. r. time-lines extend only to the first 91 days of the setting process; for, in Diagram X for pastes and in Diagram XI for mortars, the lines introduced in Diagram VII are shown on a larger scale and separated for the initial period of the hardening.

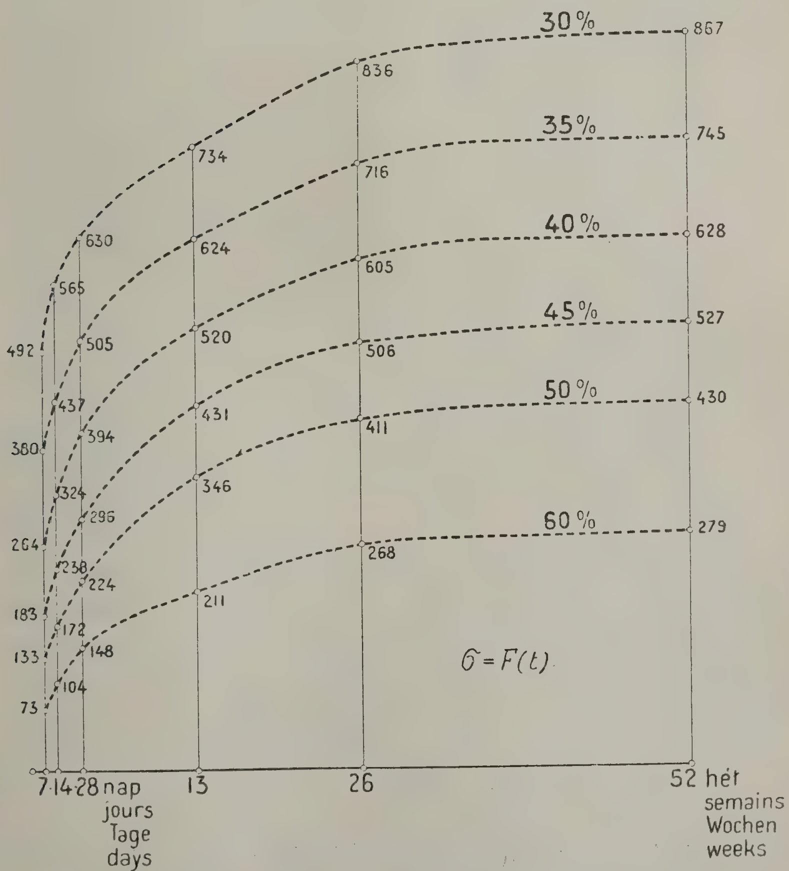


Diagram IX. Time Lines for Portland Cement Mortars.

For the purpose of making a clear and successful investigation of the time-lines, we must introduce two additional conceptions, namely, the speed and the acceleration of the hardening process.

It follows, however, from the nature of the case, that these two conceptions are adapted for inclusion in the consideration of

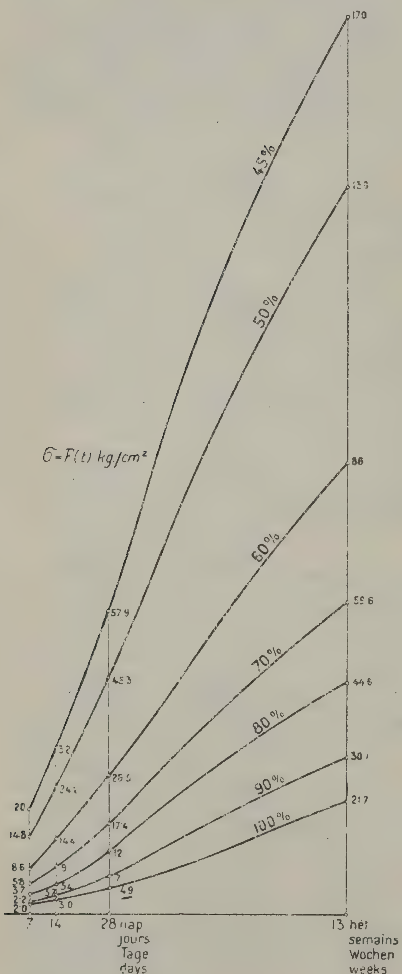


Diagram X. Time Lines for Pastes of Roman Cement poor-in-lime from 1 week to 13 weeks.

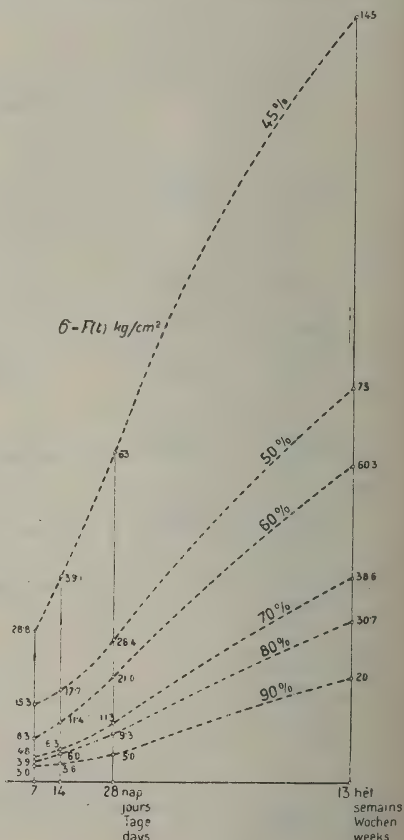


Diagram XI. Time Lines for Mortars of Roman Cement poor-in-lime from 1 week to 13 weeks.

the matter investigated, in as much as the progress of setting exhibited in the form of time lines, is just as much a function of time as, for example, the path described in any study relating to motion. In order, however, to analyse the variations in the path progressing according to some law with, the time, conceptions of speed and acceleration are indispensible. The development of the strength being of the same nature as the speed of the hardening, we must understand under „speed of hardening“ the relation borne by the change in the strength to the change in the time. The acceleration of the hardening is the relation borne by the change in the speed of hardening to the time during which the change occurs.

This is expressed analytically by the following formulae:

With r and p constant the time line is given by:

$$\sigma = F(t)$$

the speed of hardening by:

$$e = \frac{d\sigma}{dt} = F'(t)$$

and the acceleration of hardening by:

$$g = \frac{d^2\sigma}{dt^2} = F''(t).$$

In oder that $F'(t)$ and $F''(t)$ may be calculated differentially, it is necessary to cast the equation $\sigma = F(t)$ into an analytical shape.

This would demand the calculation of the results of at least five experiments, with the requisite approximation, and obviously would lead to a from which would be difficult to manipulate analytically.

The graphic method is therefore much more suited for the object of a comprehensive research. This method we propose to follow. We shall, however, give some simple formulae deduced from arbitrary hypotheses based on the results of graphical analysis but convenient for calculating approximate values, and these formulae will serve as guiding points, if from any cause the graphic method should fail us.

For example, let us consider the m. d. r, m. sz. r. and Portland cement hardening law in Diagrams XII, XIII and XIV, for Roman cements, when r = 0·6, for Portland cement pastes, when r = 0·4, and for mortar prepared with the condition p = 3. In

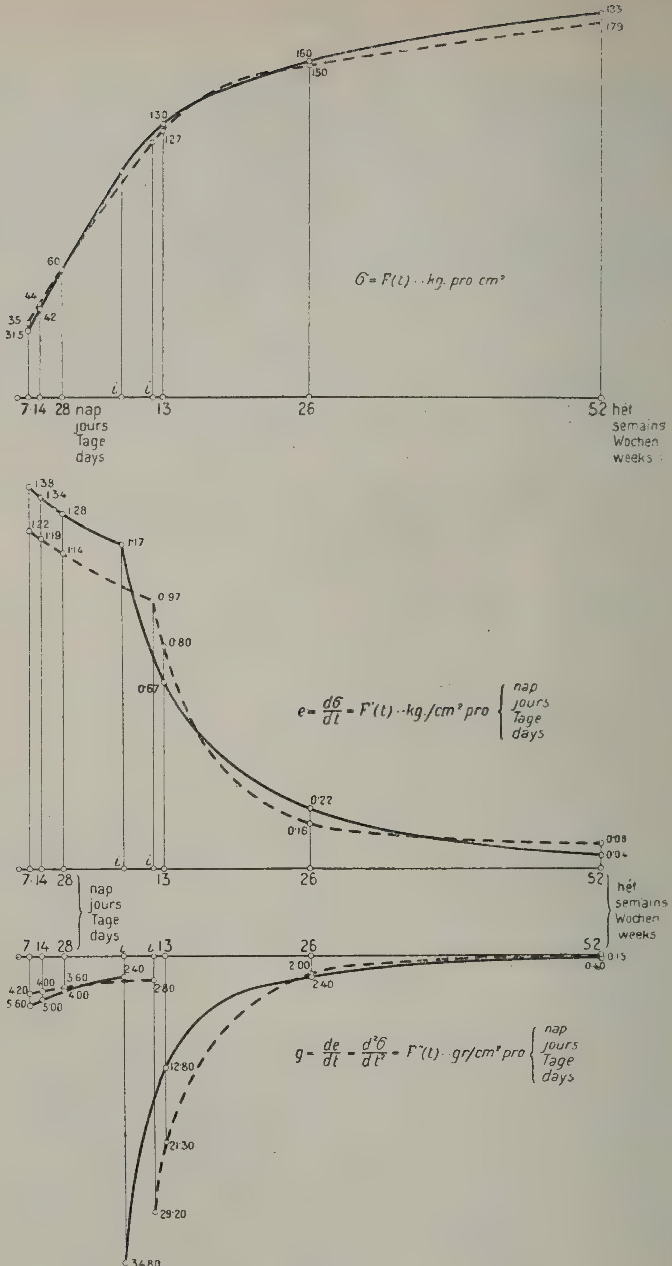


Diagram XII. Velocity and Acceleration of Hardening for Paste and Mortar of Roman Cement rich-in-lime.

Cement-Paste ————————

Mortar — — — — — — — —

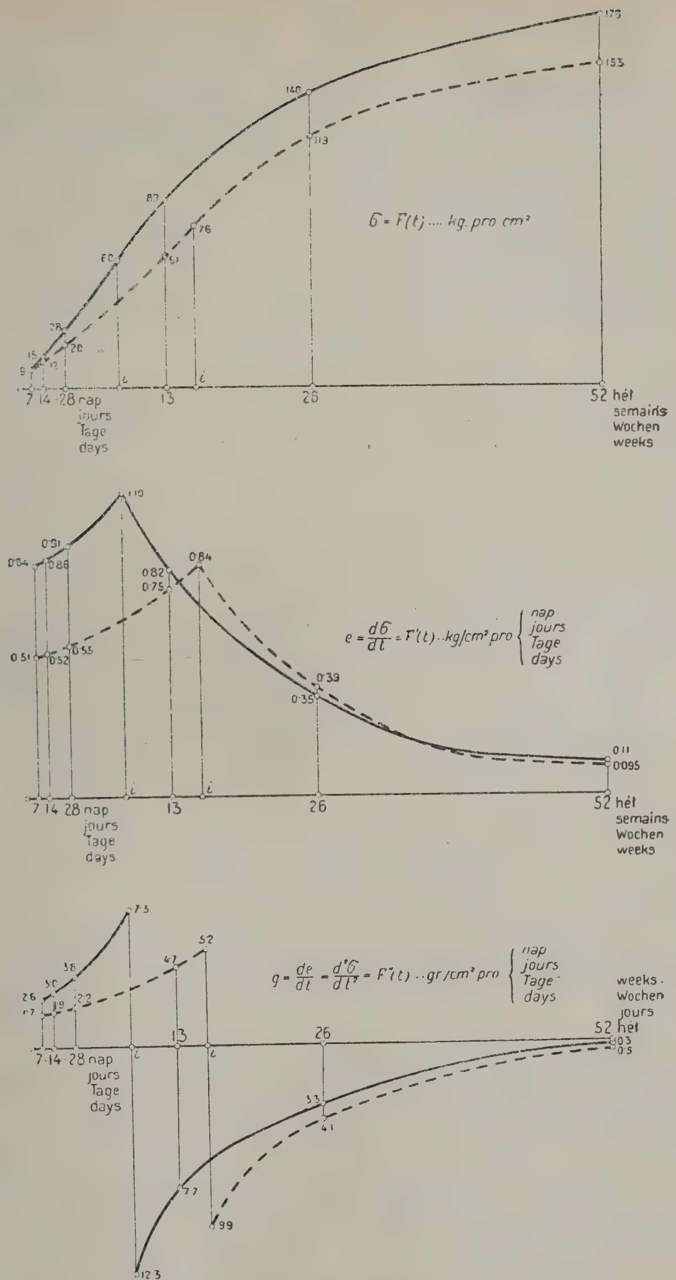


Diagram XIII. Velocity and Acceleration of Hardening for Paste and Mortar of Roman Cement poor-in-lime.

Cement-Paste ————————

Mortar — — — — — — — —

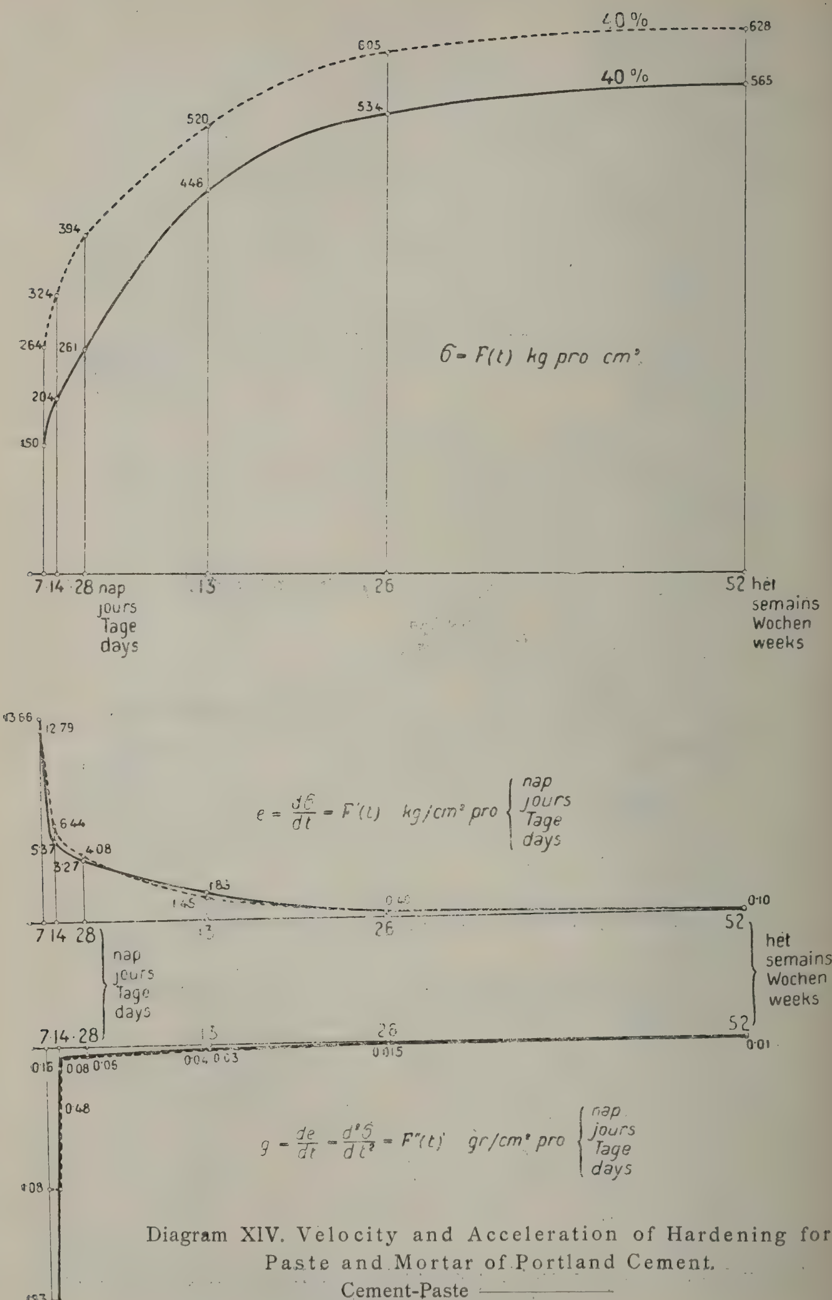


Diagram XIV. Velocity and Acceleration of Hardening for Paste and Mortar of Portland Cement.

Cement-Paste ————

Mortar — — — — — — —

the first place we draw, on the basis of results derived from experiment, the lines:

$$\sigma = F(t)$$

continuous in the case of paste, and broken (dotted) in the case of mortar.

After drawing these lines we avail ourselves of the well-known process of the graphical differentiation and draw the line:

$$e = \frac{d\sigma}{dt} = F'(t).$$

Again differentiating this graphically, we come to the line:

$$g = \frac{d^2\sigma}{dt^2} = F''(t)$$

The time-limes exhibit differences only in so far that while those of the m. d. r. and Portland cements are concave towards the abscissae, those of the m. sz. r. commence concave and afterwards become convex, that is to say, they have an inflexion, which, however, is not very pronounced.

If, however, we consider the lines $e = F'(t)$ and $g = F''(t)$ characteristic for the course of the setting velocity, we see some striking differences.

1. The acceleration of the hardening of Roman cements rich-in-lime and of the Portland cements is always negative; its absolute value diminishes, and is a maximum at $t = 0$.

The acceleration for Roman cements poor-in-lime on the other hand is positive and increases up to the point of inflexion; beyond this point it is negative, and its absolute value diminishes.

2. The hardening-velocity, which may be called the "setting-energy" is positive for m. d. r. and a maximum at $t = 0$.

The hardening-velocity for m. sz. r. is likewise positive, but reaches its maximum at the point of inflexion — in the example given, after about 4—6 weeks.

Thus the law of hardening-development, or shortly, of hardening or setting-energy, appears to be characteristically different for m. d. r. and m. sz. r.

In the case of the m. sz. r. cements, the slow development of strength is to be attributed to weak initial energy and to this also is attributable the low ultimate strength established after

setting of 7, 14, 28 days and 13 weeks. But, from the increase of energy up to the point of inflexion and the slow backward development after the maximum has been reached, it can be anderstood how m. sz. r. cements, in the beginning weak, in the later time-stages attain strengths equal to those of m. d. r. cements.

From the recognition of this fact, we can draw valuable conclusions relative to the practical application of cements and of hydraulic cements in general.

In all cases indeed in which mortar or concrete used in building operations must, after a short time, posses a given degree of strength, it is rational to employ only those kinds of cement which have great initial energy.

From the foregoing it is evident, that it is a matter of great importance in practice to know, with regard to the cement at our disposal, whether or not the strength commences with maximum energy. Of this we can convince ourselves by means of three experiments in which r remains the same (and in the case of mortars p also) and if the intervals of time between the tests are small, the strength at the beginning is determinable.

For example let us take: $t_1 = 7$, $t_2 = 14$ und $t_3 = 28$ days.

When the strength-coefficient according to t_1 is σ_1

" " t_2 " σ_2

and " " t_3 " σ_3

then according as $\sigma_2 - \sigma_1 \lessgtr (t_2 - t_1)\dfrac{\sigma_3 - \sigma_1}{t_3 - t_1}$, the time-line for the hardening is concave or convex to the abscissa.

If:
$$\sigma_2 - \sigma_1 < (t_2 - t_1)\frac{\sigma_3 - \sigma_1}{t_3 - t_1} \tag{1a}$$

then the time line is convex and it follows from this that the acceleration is positive, that is to say, the hardening does not commence with maximum energy. The initial energy, that is, the initial velocity of the hardening is, in this case, the following:

$$e = \frac{(t_3 - t_1)\dfrac{\sigma_2 - \sigma_1}{t_2 - t_1} - (t_2 - t_1)\dfrac{\sigma_3 - \sigma_1}{t_3 - t_1}}{t_3 - t_2}$$

If σ be expressed in kg per cm² and t in days, the energy is e kgs. per cm² per day.

The numerical value of the hardening acceleration is of less interest to us at present than the sign preceding it. The fact that the form of the line is convex to the abscissa has determined this as negative. We can see from our diagrams that, in this sense, the convex lines have an inflexion in the beginning and that the energy is at its maximum at the point of infiexion.

It is difficult to determine the maximum energy in the case now under discussion with simple formulae. To obtain this, we must resort to the graphic method already described.

If, however, on the last day of the setting test, for example the 28th day, it be desired to know the velocity of development, then, taking into consideration the results of two previous experiments, say those of the 7th and 14th days, the following formula gives the required velocity:

$$e = \frac{(t_3 - t_1)\dfrac{\sigma_3 - \sigma_2}{t_3 - t_2}\,(t_3 - t_2)\dfrac{\sigma_3 - \sigma_1}{t_3 - t_1}}{t_2 - t_1}$$

The result thus obtained is in kgs/cm² per day.

If: $$\sigma_2 - \sigma_1 > (t_2 - t_1)\frac{\sigma_3 - \sigma_1}{t_3 - t_1} \qquad (2\,a)$$

then the time line is concave, and it follows that the acceleration is negative, that is, the setting commences with maximum energy.

The initial energy is, in this case, likewise the maximum energy, and its numerical value is the following:

$$e = \frac{\sigma_3 - \sigma_2}{(\sigma_3 - \sigma_1)\dfrac{t_2 - t_1}{\sigma_2 - \sigma_1} - (\sigma_2 - \sigma_1)\dfrac{t_3 - t_1}{\sigma_3 - \sigma_1}} \text{ kg/cm}^2 \text{ per day.}$$

If, at any period of time during the experiment, we wish to know the deminished velocity, then, taking into consideration two known results for preceding points of time, we can obtain the numerical value from the following equation:

$$e = \frac{\sigma_2 - \sigma_1}{(\sigma_3 - \sigma_1)\dfrac{t_3 - t_2}{\sigma_3 - \sigma_2} - (\sigma_3 - \sigma_1)\dfrac{t_3 - t_1}{\sigma_3 - \sigma_1}}$$

In order to facilitate the application of the formulae, it is desirable to fix the time for the breaking in advance and to choose as the unit of time 7 days, that is, one week, and fix the times

at which the breakings shall follow according to some regular scheme, as indeed is customary in this kind of experiments.

For example, in our experiments, we employed the scheme, 7—14—28 days, or, when expressed in weeks, 1—2—4.

If we pay attention to this point in the arrangement of our experiments, then the following simple formulae furnish the energy for the unit of time of one week in kg per cm²:

If: $$\sigma_2 - \sigma_1 < \frac{\sigma_3 - \sigma_1}{3} \qquad (1\,b)$$

then the initial energy after the first week, that is, after the 7th day of settling is:

$$e = 1{\cdot}5\,(\sigma_3 - \sigma_2) - 0{\cdot}17\,(\sigma_3 - \sigma_1) \text{ in kgs. per cm}^2 \text{ per week.}$$

The increased energy after four weeks, that is, after the 28th day of setting is:

$$e = 1{\cdot}5\,(\sigma_3 - \sigma_2) - 0{\cdot}67\,(\sigma_3 - \sigma_1) \text{ kg per cm}^2 \text{ per week.}$$

If: $$\sigma_2 - \sigma_1 > \frac{\sigma_3 - \sigma_1}{3} \qquad (2\,b)$$

then the initial energy after the first week, that is, after the 7th day of hardening is:

$$e = \frac{\sigma_3 - \sigma_2}{\dfrac{\sigma_3 - \sigma_1}{\sigma_2 - \sigma_1} - 3.\dfrac{\sigma_2 - \sigma_1}{\sigma_3 - \sigma_1}} \text{ kg per cm}^2 \text{ per week.}$$

The diminished energy after four weeks, that is, after the 28th day of hardening is:

$$e = \frac{\sigma_2 - \sigma_1}{2.\dfrac{\sigma_3 - \sigma_2}{\sigma_3 - \sigma_1} - 3.\dfrac{\sigma_3 - \sigma_1}{\sigma_3 - \sigma_2}}$$

The graphic differential deduced with the approximating conditions led to results agreeing very well with the numerical values provided by the formulae grouped above, and from this circumstance it was possible to conclude that, with the method we employed, the test-samples were prepared with such uniformity, that the hardening development proceeded according to some determinable law, and that it is possible to find an expression for this law with the help of the average results obtained in the ultimate strengths.

This law for the four week "intervals" in the setting process (in the case of our experiments we tock the intervals 1, 2 and

4 weeks, in order to simplify the testing) we found capable of expression by the formulae below.

The law holds good for the four week "intervals" in the course of hardening at the point where the line, in the beginning convex, becomes concave; for this part of the line obviously lies beyond the point of inflexion.

If the values connected with the experimental results be denoted as follows:

After 7 days, in the time $t_1 = 1$, the ascertained strength $= \sigma_1$
" 14 " " " " $t_2 = 2$, " " " $= \sigma_2$
" 28 " " " " $t_3 = 4$, " " " $= \sigma_3$

then, taking into consideration the lengths of time in the scheme, the following equation gives numerically the strength σ attained in a time $t > t_3$, t being expressed in weeks:

$$\sigma = \sigma_3 + (t-4)\, e - (t-4^2) \times (0{\cdot}528\,\sigma_3 - 0{\cdot}75\,\sigma_2 + 0{\cdot}22\,\varkappa_1 - 0{\cdot}833\, e).$$

In this expression e denotes the value of the setting energy attained after the 28th day and this can be calculated by the formulae given on the basis of the experimental results already obtained; the multiplier of $(t-4)^2$ is always the absolute value of the algebraical quantity contained in the brackets.

With this formula, for example, we calculated the 91 days' or 13 weeks' strength factors on the basis of the 7, 14 and 28 weeks' experimental results, and obtained numerical values conforming well with the 13 weeks experimental results alike for pastes, mortars and concretes. Taking this fact as a foundation, we regard the determination of the hardening law even for the first 28 days, as not impossible, provided it be investigated by the help of test samples very carefully prepared in accordance with the process we have communicated, by means of breaking tests performed, as far as possible, every second day.

From this it appears it would be possible to effect a reduction of the standard time of testing, of 28 days, on a mathematical basis, down to 21 and eventually 14 days. The determination of this law, however, would have entailed the preparation of a special series of test-samples, which it was not possible to include within the already-extended scope of our present research. But, if the Congress in its wisdom should so resolve, this question could also be referred to the new committee for investigation.

Finally, these simple calculations, when based on the results of three experiments are sufficient to give full information with regard to the important properties of the cement.

We must, however, still remark, that the calculations are in so far approximate, that the deduction of the formulae is made with the condition, that the time-line is a parabola passing through the origin of the system of co-ordinates and such that its axis is parallel with the axis σ, if the line is convex, and parallel with the axis t, if the line is concave, while the origin of the coordinate system coincides with the point σ_1, t_1.

The data elaborated in this chapter all relate to results of setting under water. As we have already mentioned, the setting law of cements in air was examined at the same time by the aid of a series of experiments of like extent. These latter data are preserved in our records in the same form as those of the series presented, and the results have been studied and analysed in the same way as those here communicated.

After examining altogether 14 Roman cements, from 4 factories and besides these, also two Portland cements, we can announce in general that the cement mortars and pastes, subjected to experiments identical with the series here elaborated, lead to like conclusions, with any kind of sand, which, however, must be homogeneous. In addition to those communicated, such a series was carried out with river-sand and with quarry-sand, mixed, uniform and fine-grained. The communication of the results of experiments thus obtained in a form such as that here treated in detail, would lead to repetitions. We mention them, however, in order to indicate the extent of our researches.

VI. The Effect exercised on the Hardening by Quality and Quantity of the Sand.

The influence of sand as manifested in hydraulic-setting, has been investigated with mortars.

It would lead too far, and this report would far exceed the limit assigned to it, if the conclusions, drawn from the results of our experiments performed with sand, were accompanied by minute details such as those given in the foregoing chapter. That we drew our conclusions with the necessary circumspection, and after a thoughtful study of the experimental results, can, we think, be

gathered from the foregoing chapters, and therefore, in what follows, we present to the Congress our conclusions accompanied, at most, only by a brief justification.

The influence of sand on the setting of mortar and on the strength attainable with mortars was examined in three directions, viz:

1. The effect of the quality of the sand

2. The influence of the size-of-grain and of the uniformity of the sand.

3. The consequences attending a change in p, the proportionate quantity of sand to cement.

Ad 1. The different kinds of sands were classified and distinguished according to their purity into:

a) pure sand (Vienna standard sand and pure river-sand);

b) crushed sand (from Carpathian sand-stone);

c) earthy and clayey sand, and sand mixed with organic matter, in short, muddy pit-sand;

d) To render clearer the effect of clay on sand, we mixed, clay artificially with pure river-sand in the proportion 2·5% to 20% which we gradually increased by steps of 2·5%.

The series was prepared with like cement and with like mixing-proportions, and the development studied at the six above-mentioned intervals of time for a period of 52 weeks. From the table constructed rationally with the results thus obtained and from the time limes, which the limits of this report do not enable us to give, we drew the following conclusions:

The binding-power of the mortar diminishes with the increase in the relative quantity of foreign substances adulterating the sand.

Comparing the results obtained with crushed sands with one another and with the results for pure river-sands, we determined that, other conditions being identical, the mortar is the stronger the stronger its constituent materials and the rougher its surface.

Ad 2. In view of the fact that the size-of-grain of the sand and its uniformity or mixed condition, exercise a modifying effect on the setting of the mortars, we prepared the following list for experiments with identical cement and with the same mixing proportion:

a) Vienna standard sand, with grains remaining between the sieves of 64 and 144 perforations to the equare centimetre;

b) Vienna fine sand which has passed through the 144 sieve;

c) uniform river-sand (grains remaining between the 64 and the 144 sieves);

d) fine river-sand (under the 144-mesh sieve);

e) mixed river-sand (under the 5 mm sieve);

f) quarry-sand (under 5 mm sieve).

We determined the components of the applied mixture of river, quarry, and crushed sands by means of several siftings with sieves designated in Table 6, where also the results are given.

Table 6.

Relative Sizes of Grain in Sands of Mixed Grains.

Kind of Sand	River-Sand	Quarry-Sand	Crushed Sand
Percentage passing through 0·5 mm sieve . .	47·3	90·2	29·4
Percentage of Residue between 0·5 and 1·0 mm sieves	21·5	4·0	18·5
Percentage of Residue between 1·0 and 2·0 mm sieves	13·8	1·4	21·2
Percentage of Residue between 2·0 and 5·0 mm sieves	17·4	4·4	30·9
Total percentage . .	100·0	100·0	100·0

We deduced from the results, that:

Mortar prepared with sand of mixed grain surpasses in goodness and strength a preparation of a similar kind with sand of uniform sixe of grain, and a similar kind of mortar prepared with fine sand of one and the same quality.

The first part of our experience receives its explanation from the fact that, with sand of mixed grain, there is the smallest total of interstices.

In consequence of the difference in size of the grains, the smaller particles fill up the spaces between the greater particles, and accordingly, in case the conditions and mixing-proportions remain unchanged, absolutely (and with regard to the total quantity

of interstices, also relatively) the greatest quantity of paste comes into the mortar. We say absolutely, because the maximum apparent specific gravity of sand is the greatest, and relatively, because, at the same time, the total volume of interstices is the smallest. Thus, under like conditions, it is more probable that the grain of sand will be completely embedded in paste, and the uniform distribution of the paste among the grains supervene more surely than in sands where the grains are uniform, and therefore the volume of interstices greater.

According to our experiences, sand with uniform coarse grains is better for preparing good mortar, than sand with uniform fine grains, a circumstance which can easily be explained from the action of the quantity of nearly-identical paste. The paste is destined to stick together and bind the individual grains of sand. This can happen naturally only at the surface of the grains. A binding and sticking together of uniform degree-of-strength is probable when a uniform quantity of paste comes to every unit of surface. Considering that the total surface area for sand of smaller grain is considerably greater than for a like weight of sand of coarse grain, it follows that more paste comes to the unit of surface in coarse-grained sand than in fine sand, and consequently the binding power is smaller in the fine sand, a circumstance which our experiments have confirmed.

We consider it desirable, in the interests of the correct working-up and application of cements in practice, to express the following summarized conclusion, viz, that the best material for making mortar is river-sand of coarse, mixed grain; for sand can be obtained from rivers such that it is pure and consists of grains of different size.

ad 3. For an adaquate investigation of the effect due to change in the relative quantity of sand in the mortar and perceptible in the course of the hardening, we made the following series of experiments. The proportion of cement and sand, p, varied from 1 to 6. At the same time, the proportion, r, of water mixed in was successively changed by increments of 0·1 between the minimum mixing-limit and the maximum water-absorbing limit.

In working up the results obtained in this series of experiments by collecting them in appropriately grouped tables and by constructing diagrams of the sand lines and of the identical resistance lines determinable with successive differences of 10 kg σ, we

directed special attention to determining whether, at the limit of characteristic difference in the mortar-material, that is, when the mixing-proportions correspond or nearly correspond with compact and with porous mortars (with fat and with thin mortars), the cement, with an identical proportion of water, develops its maximum binding-capacity.

We could determine in advance by our method of calculation the quantity of sand, p, corresponding with the transitions, for every r.

According to our diagrams, every time-line has a maximum, and this p value, or proportion of sand, is in fact always determinable for compact and porous mortars for any particular value of r, and is formed in the neighbourhood of, and somewhat below, the p calculated theoretically, that is, in the characteristically compact-mortar region.

We could read from the diagram the mixing-proportion corresponding with the maximum; likewise the paste- and mortar-content corresponding with the mixing-proportion. We found that the mortars in our experiments attained their maximum strengths when the volume of the paste was 1·1 times the smallest possible volume of the interstices in the sand.

For the information of practicians, we may remark that the transition from compact to porous mortar, with the customary dosing is to be expected, if the mixing proportion is given in weight, at about from 1 : 4 to 1 : 5, that is, when $p = 4$ or $p = 5$, which corresponds nearly with the 1 : 3 mixing-proportion in volume which is now extensively used in practice. Compact mortar of a kind, in which the cement develops the maximum of its binding-capacity, should be prepared with somewhat less sand, that is, with a somewhat lower sand-proportion factor.

VII. Influence of the Quality and Quantity of Gravel on the Hardening.

If we employ gravel also in hydraulic-binding, the conglomerate body formed with the cement, is called concrete. We have investigated the effect of gravel in hydraulic-binding with concretes.

Preliminary, so-called tentative, experiments acquainted us beyond doubt with the fact, that the consequences of variation in

the water-proportion are of a similar nature, in the case of concretes to those in pastes and mortars, as far as the attainable strength is concerned.

The circumstance, that it is less easy to maintain the exact quantity of water with concretes than with cements, rendered the investigation of the former a matter of very great difficulty. The series of researches with cements was accomplished with test-samples of 353·5 cm^3 volume and the thorough drying of the sand required for these samples was effected only by a great expenditure of labour.

It was, however, necessary that the test-samples prepared from concrete should have side lengths of 30 cm and 50 cm, partly to counteract the difficulties of manipulation caused by the greater size of the gravel-grains, and partly in order that the results which we might establish should approach those obtained in practice. The preparation, however, of these samples of 31·6 and 125 litres volume respectively, in such large numbers as our extensive experimental series demanded, would have called for a quantity of completely-dried sand and gravel which we could not provide on the premises and with the instruments at our disposal.

Accordingly, before preparing the test-samples, we determined the degree of moisture, that is, the relative water-content of the sand and gravel to be worked-up, by taking averages obtained in the drying of specimens of the materials, and besides this, we determined also their water-absorbing capacity.

The difference of the water-absorbing capacity and the degree of moisture determined gave the relative water-content, which the sand and the gravel draw directly from the paste-water, and use for their own moistening. Therefore, it was necessary to determine the differences for all the material, in order that we might be able to fix numerically the corresponding correction, or rather, grade for the water-factor r.

In the Vienna standard sand we determined only the specific weight and the maximum apparent specific gravity whereas, in addition to these, we had to ascertain, in the case of other sands used in the tests, the degree of moisture, the specific weight of the moist material and the water-absorbing capacity, all separately.

In determining these factors we made use of the following method:

The maximum apparent specific gravities of the cements and gravels were mea sured in a vessel having an aperture below, provided with a tap. First we measured into the vessel sufficient dry sand or gravel to fill it. Into the vessel filled with the desiccated material we introduced water slowly from below through the tap, and this, slowly rising, drove out the air in the interstices of the material. As the water appeared above the surface of the sand or gravel, the material shrank together, its volume being considerably diminished.

Measuring the diminution in volume and the weight of the material when saturated with water, we found that the increase in weight gave the weight of water absorbed and the content of the interstices filled with water in one total. After the weighing, we let-off the water again through the tap, until the exudation was no more perceptible. After the draining-off of the water, another weighing enabled us to determine the weight of water absorbed in the material. The data thus obtained afforded a sufficient basis for the necessary calculation.

This fatiguing measurement, demanding much circumspection and involving great loss of time, was repeated by us with all sands and all gravels at least four times, in vessels of the three sizes of 31, 117, and 1000 litres respectively. The great difference in the volumes of the vessels is justified by the fact, that the loose materials suffer a compression through their own weight. We wished to ascertain the effect of this with our experiments, in order that we might be able to take it into account in determining the weight of the test-samples, if it should not prove to be negligeable. With dry sand and dry gravel, however, we did not perceive any compression due to the weight of the materials themselves.

The exactitude of the process of preparing the concrete test-samples, that is to say, the quality of these, was likewise controlled by the calculation of their weights in advance and by the weighing of the prepared samples. With regard, however, partly to the fact that interstices of the gravel left in the concrete are not filled up with mortar or cement, but more especially in view of crumbling in the gravel-material eventually arising from its more violent manipulation, and, still further, with regard to the disturbing circumstances which may arise from the heterogeneous

nature of the gravel-material, we regarded a greater divergence (maximum 5%) in the calculated weight for concrete test-samples as permissible.

The development of the hardening in concretes was not examined with the water lines, that is, with gradual increments of 0·05 in the water-proportion, but the investigation was carried out with two water-proportions, viz, those which are most important from the point of view of the application of concrete in practice. These are known in practice under the names: earth-moist concretes and plastic concretes. Our definition of these two kinds of concrete is as follows:

a) Earth-moist-concrete is, to the touch, like humid earth, remains together when pressed in the hand, does not spread out in the course of manipulation under ramming tools, and begins to sweat slightly only at the limit of compactness attainable.

b) Plastic concrete is like thick mud, sticks when taken in the hand, spreads out when worked with ramming tools, and sweats vigourously even at the beginning of the advance towards compactness.

We have already had occasion to state, that the strength attainable with test-samples of one and the same composition decreases with the increase of the dimensions of these. The decrease is material in relatively small bodies, but immaterial in relatively large ones. As we have already observed and proved in Table V, there were no noteworthy differences between the strengths of tested cubes of 31·6 and 50 cm side-length respectively. This is the reason why we carried out our series of concrete-tests with samples of a side-length of 31·6 cm, that is, of 1000 square centimetre side-surface area and 31·6 litre volume.

The concrete test-samples were kept, until the arrival of the moment for breaking, within a covering of moist sand. The Committee adopted this mode of preservation in its researches with concrete because, in the great majority of cases, this corresponds better with the circumstances of setting for concretes existing in practice than the process of setting under water. It was, however, also necessary to choose this method for reasons connected with locality and cost of material; for, with the alternative method it would have been impossible for us to provide so many

tubs of suitable dimensions as the great number of our concrete tests would have demanded.

The scope of our investigation by experiments with concretes may be signalised as follows:

From six varieties of Roman cement and one of Portland cement were prepared earth-moist and plastic samples, as defined above, that is, two series of samples differing from each other with regard to the proportion of water used up. Thus fourteen series were prepared altogether 8000 concrete cubes — in consideration merely of variety of cement and water-proportion.

The progress of hardening was determined after 14 and 28 days, and then after 13 and 52 weeks.

With regard to the scope of the enquiry, we must further mention that, in order to be able to bring the strengths attainable with pastes and mortars into relation to those which were to be determined with concretes, that is to say, in order to be able to compare the binding-capacities of one and the same cement appearing in different preparations and eventually to draw conclusions, we again made parallel series of experiments with cements used in concretes, and with the concrete samples, similar to those which we have previously described in our study of the properties of cements. Naturally the nature of the comparative study required, that the pastes and mortars intended for this object should be prepared with the same water-proportion as was used for the concretes investigated.

In view of the very different properties of cements, the different water-absorbing capacities of the sands employed, and especially to the great number of different kinds of gravel available, we regarded as identical, as far as water was concerned, any pastes, mortars and concretes which had the same physical description or consistency. Thus, with the results of our experiments with paste and mortar here noted, we were placed in a position to acquire information concerning the strengths attainable with pastes, mortars, and cements not only of identical water-proportion but also of identical consistency. Knowing, however, that the strength determined by experiment diminishes with the increase of the dimensions of the sample tested, we determined, in order that we might eventually be able to establish accurately the relation existing between the strengths of concretes and those of mortars used

in concretes, to include — parallel with the concrete-experiments — a series of mortar-experiments in which the mortar cubes were identical in size with those of the concrete experiments.

With the concrete experiments we desired to elucidate the following questions:

1. The influence exercised by the method and extent of manipulation on the strength attainable.

2. Has the change in the water-proportion any effect on the setting, and if so, what is the nature of the effect?

3. The influence of the quality of sand used for cements on the strength attainable with concretes.

4. Is there a determinable connection between the strength of concrete and the strength of mortar used in concrete?

5. The effect of the quality of the gravel on the strength of the concrete.

6. What is the nature of the effect exercised on the course of setting by a change in q, the relative quantity of gravel?

7. Are there differences in the breaking-limits in the various directions in which it is possible to apply the force?

Work applied in the course of Compressing.

That the mode of manipulation and the quantity of work applied are matters of indifference, has been repeatedly established and confirmed in the preceding pages. This statement is also completely confirmed in the case of the concrete tests, provided that, for the manipulation or compressing, we regard the weight of the test samples calculated beforehand — accurately, or within the limits of error known from the preceding part of this communication to be permissible — as the standard of measurement suitable for such manipulation or compressing of the test-samples. For in spite of the fact that the manipulation of our concrete test-samples was effected by a great variety of different methods — as, partly on account of the varying physical condition dependent on the mixing and the water-proportion, and partly on account of the differing physical properties of the materials worked up, it would have been impossible for us to attain the object above indicated — the course of setting remarked in concretes still exactly follows the laws found for pastes and mortars in all points.

The law of the development of hardening, which we have observed in our extended concrete experiments, and its identity with what we found for pastes and mortars, verifies the accuracy of our preceding statement beyond all question.

Influence of the Quantity of Water.

The development of hardening in concrete decreases in general with the increase of the quantity of water. The forms of the water-lines and time-lines are in every respect similar to those communicated in detail for pastes and cements; hence also the laws which can be deduced from these lines cannot but be concordant.

Influence of the Quality of Sand on the strengths of Concretes.

This question we investigated in the following manner. We carried out series of experiments with the above-mentioned cements, in the physical conditions and with the mixing proportions communicated in the answer given to Question No. 6 and further, with the following combinations of different kinds of sand and gravel:

a) river-sand, river-gravel;

b) river-sand, lime-stone gravel;

c) river-sand, basalt gravel;

d) quarry-sand, lime-stone gravel;

e) quarry-sand, basalt gravel; and finally, in addition to these, tentative experiments with:

f) quarry-sand, brick gravel;

g) river-sand, brick gravel.

From the results arrived at with this series of experiments, which we carried out in great detail for the sake of studying in particular the influence of the properties of the gravel (a matter which is to be discussed later) we have abundant opportunity for deriving information relative to the influence of the quality of the sand.

In the course of the experiments it was found, that the quality of the sand has a striking effect on the quality of the concrete. It was remarked that, with coarse, pure sand such, for example, as our river-sand of mixed grain — the concrete attains a much greater strength than with fine-grained quarry-sand.

Our experiments disclosed an enormous difference in the capacities of Roman cements poor-in-lime and Roman cements rich-in-lime. Whereas with m. d r. and with Portland cement we obtained very different, but yet acceptable values, even with fine-grained quarry-sand, the m. sz. r with the like quarry-sand could not attain any noteworthy strength even after 26 and 52 weeks, that is, after a year's setting. The lamentable results of our concrete experiments were not alone in confirming the unsuitability of Roman cement with fine-grained sand for application in practice, but this was previously indicated no less clearly by the feeble setting-capacities of the mortars prepared with such sand.

We consider it a duty to express our conviction, that the use of fine-grained quarry-sand for cements should be avoided as much as possible, and that Roman cements poor-in-lime, with fine-grained quarry-sand, are not suitable for the preparation either of mortar or of concrete.

These strikingly bad results are, in our opinion, attributable partly to the circumstance that quarry-sands contain a much greater quantity of organic and other elements of an impure kind than the river-sands obtained by dredging, partly, and indeed principally, to the fact, that in the quarry-sands there are great numbers of exceedingly fine grains, and these, during the process of saturation, gather so much water on their relatively large surfaces, that, in the process of setting, they dilute the actual binding material, the paste, and according to the evidence provided by the water lines, this dilution has a permanent effect on the course of the setting.

Relation between the Hardening of Mortar and that of Concrete.

In order to determine this relation, the above-mentioned mortar-tests were carried out with test-cubes uniform in size with the concrete-cubes and of which the mixing-proportions and relative water-content were identical with those of the mortar used for the concrete. These groups of experiments were made with two water-proportions and four cements, altogether eight series, and durations of setting comprising 14 and 28 days, and 13 and 52 weeks. The results of these experiments are given below in Table 7, to enable attention to be directed to the surprising experience, that the strength attainable with concrete — so long as the gravel

used for the latter is stronger than the mortar — is always nearly equal to the strength of the mortar used for it. For the strength of concretes, then, the criterion is given by the quality of the mortar contained in them.

With more exhaustive experiments it would be possible to demonstrate, from this similarity in the strengths of the mortar and concrete, that mortar test-samples of suitable dimensions can be substituted for the concrete samples, provided their composition be identical with that of the mortar used for the concrete.

Table 7.

Comparison of the Strengths of Mortar and Concrete Cubes of 30 cm in length, prepared with Roman-Cement rich-in-lime.

Time of Setting	20 cm Mortar Test-Samples made with River-Sand						30 cm Concrete Test-Samples with River-Sand and River-Gravel					
	Earth-Moist			Plastic			Earth-Moist			Plastic		
	Mixing-Proportion			Mixing-Proportion			Mixing-Proportion			Mixing-Proportion		
	1:3	1:4	1:6	1:3	1:4	1:6	1:3:3	1:4:4	1:6:6	1:3:3	1:4:4	1:6:6
28 days	40.7	31·3	24·5	28·9	19·8	9·8	44·8	34·4	24 4	28·5	20·3	12·5
13 weeks . . .	59·0	53·0	39 9	49·0	33·5	20·2	69·5	48·0	37·0	48·5	31·0	21·0
52 weeks . . .	89 5	80·0	69·0	76·0	53·5	33·5	86·0	85·0	49·0	67·0	51·5	29·0

Influence of the Quality of the Gravel on Concrete.

Endeavours were made to determine this question by introducing corresponding series of experiments corresponding with the seven combinations mentioned above and classified in the answer to question 3.

In our concrete-experiments, we obtained the experience that the quality of the gravel material, its degree of hardness, and its strength, cannot make themselves felt in concrete to any calculable extent This is shown by the results of our experiments obtained with identically-mixed concretes prepared with lime-stone gravel and with basalt-stone gravel and given by way of illustration in Table 8. In these we obtained identical strengths with two mediums of very different degrees of hardness and strength, their ultimate strengths

corresponding with the strengths of the mortar used in the concretes, in accordance with what was demonstrated under the preceding heading.

In Table 8 we give results connected with this question obtained with Roman-cement concretes rich-in-lime, prepared with small lime-stone gravel of a breaking-limit of 600—1000 kgs./cm² and with small basalt-stone gravel of a breaking-limit of 3000—3500 kgs./cm², that is, about four times harder than the lime-stone.

Table 8.

Concrete prepared with Roman Cement rich-in-lime, River-Sands and Gravels of differents Strengths.

Time of setting	Lime-stone gravel									
	earth-moist					plastic				
	Weight-proportions and water-proportions of materials mixed					Weight-proportions and water-proportions of materials mixed				
	1:3:3	1:3:4	1:4:4	1:4:6	1:6:6	1:3:3	1:3:4	1:4:4	1:4:6	1:6:6
	0·65	0·675	0·725	0·775	0·875	0·775	0 8	0·9	0·95	1·15
14 days . . .	41·1	41·0	33·0	33·2	23·1	16·9	20·2	13 6	16·8	10·4
28 days . . .	45·7	43·9	40·1	44·3	25·0	21·9	24·6	19·9	22·9	13·4
13 weeks . . .	66·5	66·0	59·5	61·5	42·5	35·0	39·5	32·3	32·2	26·5
52 weeks . . .	120·5	112·0	103·0	98·5	70·0	80·0	81·0	70·0	68·5	51·0

Time of setting	Basalt-gravel									
	Weight-proportions and water-proportions of materials mixed					Weight-proportions and water-proportions of materials mixed				
	1:3:3	1:3:4	1:4:4	1:4:6	1:6:6	1:3:3	1:3:4	1:4:4	1:4:6	1:6:6
	0·666	0·668	0·738	0·782	0·882	0·866	0·888	0·938	0·982	1·082
14 days . . .	30·6	28 9	26·9	25·2	20·6	15·0	14·0	11·8	14·1	10·6
28 days . . .	42·5	40·9	35·3	33·4	23·4	21·5	19·9	18·0	19·8	15·3
13 weeks . . .	58·5	59·5	51·8	54·0	42·0	36·5	35·8	29·2	32·7	24·0
52 weeks . . .	116·5	113.0	100·5	109·5	88·0	73·3	74·0	61·0	73·0	52·5

Although from the preceding it is perhaps superfluous, we must again remark that, according to our experiments, the hardness of the stone is only indifferent to the strength attainable with

concrete so long as the stone is not weaker than the mortar, for in this case the strength of the stone forms the limit for the result attainable with the concrete.

The mortar in concretes prepared with strong gravels breaks sooner than the gravel — in concretes prepared with weak gravels the gravel, because breaking-limit is attained sooner under the application of increasing force.

In a word, the limit of resistance of the concrete is fixed by the weaker element contained in it.

Table 9.

Concrete prepared with Roman Cement poor-in-lime, with Rough and with Smooth Gravels.

Time of Setting	River Sand, earth-moist. Mixture, Weight and Water Proportions					Basalt Gravel, plastic. Mixture, Weight and Water Proportions				
	1:3:3	1:3:4	1:4:4	1:4:6	1:6:6	1:3:3	1:3:4	1:4:4	1:4:6	1:6:6
	0·56	0·58	0·63	0·67	0·77	0·66	0·68	0·78	0·82	1·02
14 days . . .	10·5	12·3	7·4	9·1	6·2	5·4	6·0	4·9	4·5	2·7
28 days . . .	12·5	14·3	9·2	11·9	7·5	6·4	8·1	5·5	5·5	3·2
13 weeks . .	33·9	38·4	18·7	13·8	9·6	21·2	16·6	8·0	8·5	5·0
52 weeks . .	114·5	110·5	86·0	39·0	31·3	79·0	84·0	55·0	42·4	22·3

Time of Setting	River Sand, earth-moist. Mixture, Weight and Water Proportions					River Gravel, plastic. Mixture, Weight and Water Proportions				
	1:3:3	1:3:4	1:4:4	1:4:6	1:6:6	1:3:3	1:3:4	1:4:4	1:4:6	1:6:6
	0·56	0·58	0·64	0·68	0·80	0·66	0·68	0·80	0·84	1·08
14 days . . .	9·1	7·9	6·1	5·2	4·3	4·9	4·8	3·3	2·8	2·1
28 days . . .	10·8	10·9	7·8	6·6	4·8	6·1	6·4	3·9	3·5	2·4
13 weeks . .	35·9	33·4	22·5	10·0	5·6	23·7	21·6	13·4	6·5	2·6
52 weeks . .	96·3	90·6	68·5	58·5	29·4	72·3	69·5	49·5	38·4	16·9

With this we regard also as decided, the long-disputed question, as to whether rough or smooth gravel gives the better concrete, for according to our experiments, with appropriate mixing no calculable nor note-worthy difference between these two varieties became apparent in the strengths attainable. This is shown in Table IX which gives the results obtained with concretes prepared from Roman cements poor-in-lime, with rough and with smooth gravels.

Hence in practice, the decision on this question can be left simply to the competition between the market-prices of the different gravels.

A few words must be devoted to the results we obtained with concretes prepared with brick gravel; for they are sufficiently startling. Of these it can be stated that, until the mortar attains the degree of strength of the brick, the strength of the mortar fixes the breaking-limit of the concretes, just as basalt or lime-stone gravel in the concrete would so fix it. However, after the further advance of the setting in the mortar, the weaknes of the brick becomes apparent.

Table 10.

Comparisons of Strengths of Concretes prepared with Roman Cement rich-in-lime, and with Brick and Lime-Stone Gravel.

Time of Setting	Quarry-Sand Brick				Quarry-Sand Lime-Stone			
	Proportion of weights of materials mixed				Proportion of weights of materials mixed			
	1 : 4 : 4		1 : 6 : 6		1 : 4 : 4		1 : 6 : 6	
	earth-moist	plastic	earth-moist	plastic	earth-moist	plastic	earth-moist	plastic
28 days	23·1	21·7	17·0	13·6	26·5	18·2	23·1	14·1
13 weeks	39·0	33·2	25·1	22·0	39·0	30·0	32·1	20·7
52 weeks	79·5	64·0	49 0	45·5	58·5	49·0	55·0	35·0

In concretes prepared with brick-gravel, moreover, the great water-absorbing power of the brick-material manifests itself in the

influence it excercises on the development of strength during the setting. It is, in any case, scarcely possible to saturate the brick-material adequately with water, and accordingly it abstracts much water from the mortar, and in doing so has precisely the opposite effect on the setting to that exercised by fine quarry-sand. Thus by diminishing the water-proportion of the mortar, the energy and velocity of setting are increased, so that even cements poor-in-lime — which, with other ingredients, do not receive their due — attain quite noteworthy strengths in concretes with brick-gravel. This we can attribute to no other cause than the decrease in the water-proportion of the mortar. This favourable circumstance also exercises its influence on mortars in brick walls.

Effect of the Quantity of Gravel on the Strengths attainable with Concretes.

For the purpose of inquiring into the influence of the quantity of gravel, we used, in the field of experiments already described, concrete test-samples of the following proportions of material by weight:

$$c : p : q = 1 : 3 : 3; = 1 : 3 : 4; = 1 : 4 : 4; = 1 : 4 : 6 = 1 : 6 : 6,$$

altogether, five different quantities of gravel.

Constructing tables and diagrams — especially water lines — from the results, we find in general that, until the quantity of mortar is such that it is capable of occupying completely the sum of the interstices between the grains of gravel or advances beyond this quantity, the concrete strength, in case the same mortar is used, scarcely changes and is very near to the strength of the mortar. In this respect we obtain perceptibly the best result, if we choose the factors of the mixing-proportions so that, passing beyond the standard-limit for compactness, the actual content of mortar is in the ratio of about 1·1 or 1·15 to 1 to the quantity necessary to satisfy the standard, and at the same time the volume of paste in the mortar is about 1·1 times the sum of the interstices between the grains of sand. Under these conditions, with careful work, it is possible to satisfy the requirement that every grain of gravel shall be completely enclosed in mortar and every grain of sand in paste. As the quantity of gravel passes the limit,

that is to say, the condition for compactness in the body, the strength diminishes with the increase in the quantity of gravel; for with the most careful manipulation, it is impossible in this case to prevent some grains of gravel remaining unenveloped by mortar-material or, from obtaining so little of the relatively small quantity of mortar, that the necesseary adhesion is not insured.

In practice it is desirable, for the purpose of preparing uniform and compact mortar and concrete, to work with a greater proportion of water than has hitherto been customary, for two reasons, viz:

a) To render dry concretes and mortars suitably compact, demands in practice much difficult, expensive, and careful labour, white uniformity of structure, and uniform distribution of the paste cannot be arrived at completely; but uniform compactness can with some small increase in the degree of moisture, be appropriately secured with a materially smaller amount of labour.

b) The more-easily attained greater compactness compensates in some measure for the decrease in the binding-capacity caused by the increase in the proportion of water.

Briefly summarizing what we have said in this connection, we can pronounce, on the ground of the results of our experiments that, from like materials, concretes of greatest strength can be prepared by using the mixing-proportions which satisfy the conditions of the compact sample.

The Effect of Differences in the Directions of Ramming and of the Application of Strain respectively.

The fact being known that the direction taken by the burdening of concrete is, in practice, generally the same as that of the ramming, whereas it is usual to determine the breaking limit by experiment with a pressure exercised perpendicular to the direction in which the sample was rammed, we accordingly attributed importance, from a practical point of view, to a determination of the question, as to whether any difference in the strengths of concretes in these two directions is determinable.

In order to arrive at a final decision on this point, the Committee prepared separate parallel series of samples, so that it might be possible to test perfectly identical concretes as to their strengths in these two directions. With this procedure, however, it

was not possible to establish divergences, for, within the limits allowed in the experiments, variations showed themselves in both directions.

As far as this matter is concerned, we can pronounce, on the ground of our experiments, that the ultimate strength of concrete remains the same, whatever may be the direction of the force acting against it.

This concludes the brief report of the extended research into the properties of the two characteristic kinds of Hungarian Roman cements, which the Budapesth Congress of the International Association for Testing materials entrusted to us and clears up the question as to the two kinds of Hungarian Roman cement, a research continued for years, so that, from the properties investigated, we might derive conclusions of scientific value and meet the requirements of practice.

This research, however, was extended to include every description of experiment with Portland cements, so as to enable us to establish comparisons between these and the Roman cements. In the course of our work, we arrived at the conviction — as can be verified by the data connected with the extensive experiments we carried out with Portland cements — that, whereas the chemical and physical laws are almost identical for Portland and for Roman cements, our method of testing, on which we based the entire research, can be employed with perfect success for Portland cements also.

Thus, also in the case of Portland cements we were successful in preparing samples for testing, such that their weight accorded exactly with that ascertained in advance by calculation; accordingly, the method provides unexceptionable means of controlling the quality of the test-samples in the case of Portland cements also.

It was observed, that test-samples prepared by this method give, in consequence of their more uniform structure, more uniform results and, on account of their compactness, better ones, than test-samples prepared on the standard tests method with the same proportions of mixed materials.

Finally, we were able to establish that, besides their considerably higher strength-values, Portland cements present no other considerable differences as compared with Roman cements.

The circumstance, that our conclusions and analyses follow directly from the results of experiments, is the best proof of the excellence of the testing process, which we employed.

In the belief and on the ground that we have duly fulfilled, by our research, the task entrusted to us by the Congress of the International Association for Testing Materials, we beg to conclude our report by again desiring ihe Congress to resolve that our method, appropriately elaborated, be accepted for general use and that the determination of the details be entrusted to a Committee to be newly elected.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

V^TH CONGRESS, COPENHAGEN 1909.

XV

ON THE METHODS OF TESTING RUBBER.

By **E. Camerman**, Brussels.

Since the Congress in Brussels 1906 no important alterations have occurred in the methods of testing rubber by chemical analysis. Those treated on by the President of Committee 35 are still in practice.

Interesting observations on the analysis of rubber have been made especially by:

Herbst, Gummi-Kalender 1908. — Le Cautchouc et la Gutta Percha, Paris, No. 49, 51, 53 of 1908.

Schwartz, ibidem No. 42 and 43 of 1907 and above all by Rudolf Ditmar in his work "Die Analyse des Kautschuks, der Gutta-Percha, Balata und ihrer Zusätze", Wien und Leipzig 1909.

The most efficient contribution to the problem 35 is given in the report of M. P. Breuil on the mechanical tests of rubber.

This interesting paper has been published in extenso in French as Supplement to the Congress papers.

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XVIII1

CONTINUOUSLY REPEATED TESTS ON PAPER.*)

By Prof. **A. Rejtő** of Budapesth.

Translated from the French by A. R. Liddell, Charlottenburg.

Continuous repetitions of a given manipulation or of a given strain play an important part amongst the methods of testing materials.

As a result of this and because all the materials are subject to the laws of nature, we hope that the results obtained on papers submitted to repeated tests will be of general interest.

To prevent misunderstandings, however, we shall first set forth the principles of permanent deformation.

Bodies submitted to strains undergo two kinds of deformation — an elastic and a permanent one.

During the occurrence of permanent deformation the external force may be taken to have overcome the internal friction.

In certain materials the internal friction increases steadily up to a certain limit, while in others it remains constant.

The shapability or "capability of being fashioned" of the materials is in the first case called "tenacity" and in the second „malleability".

Paper is an elastic and tenacious substance.

Under the influence of tensile tests continued to the point of rupture of the material the external work may be considered as overcoming the sum of the amounts of work represented by elasticity and tenacity respectively.

*) Abstract of the report published in german in the Supplement to the Congress papers.

To facilitate the comparison, we must determine the relation between the external work and the weights of the samples (kgs.). Let us call this value $A_{kgs.}^{mkgs}$ Eliminating the elastic work, we obtain the work necessary to overcome the internal friction, that is to say, the value of the tenacity. Let us call this value $Z_{kgs.}^{mkgs}$

Repetition of a Longitudinal Strain.

During the repetition of a strain which is also constantly increasing, the paper each time undergoes a measurable permanent deformation and in consequence each time loses a measurable quantity of its tenacity.

During the repetition of a strain with the limit constant and the external force below the elastic limit, the permanent deformation is not measurable. If, however, we repeat these strains without allowing the paper time to rest, the permanent deformation becomes measurable. This can be continued till the sum of the work done in the production of these small deformations reaches the value of the tenacity.

For a constant limit of force, the number of repetitions (J) depends on the tenacity ($Z_{kgs.}^{mkgs.}$) and on the relation existing between the external force (P_1) and the breaking force (P_z) of the test-sample.

The mathematical expression of this relation is:

$$\log J = \mathrm{tg}\,\varphi \,.\, \log Z_{kgs.}^{mkgs.}$$

whence

$$J = Z^a \left(\frac{P_z}{P_1} - 1\right) \tag{4}$$

To make the formula independant of the dimensions of the test-samples, the tensile strains in terms of the unit of sectional area must be introduced into the calculation instead of the total force. In this case our formula becomes:

$$J = Z^a \left(\frac{p_z}{p_i} - 1\right) \tag{4b}$$

The Influence of Repose in the Loaded and in the Unloaded Conditions. If we allow the body to rest in the unloaded condition, we see that the elongation produced in it by a preceeding strain diminishes, and in this way its tenacity increases. The result is that the body will withstand a greater

number of repetitions (J). If the body be kept in a loaded condition during the intervals between the repetitions, it undergoes a surplus elongation, which diminishes its tenacity in such a way that the number of repetitions (J), which it will be able to withstand, will be diminished.

Bending and Folding.

The resistance of paper to repeated bendings and foldings has hitherto been determined by hand treatment. It is now made with the help of the Schopper folding apparatus.

We may now consider the Schopper method from the point of view of the internal friction of the materials.

As a result of the pull (R) excercised by the springs, the papers undergo a tensile strain P_r.

As a result of the regular bending, the fibres at the convex side of the paper undergo a tensile strain p_h.

The tensile stress of the fibres will then be $p_1 = p_r + p_h$.

Substituting the values P_r und P_h, we obtain the value of the tensile stress p_1:

$$p_1 = \frac{R}{15\delta} + \left[p_a - \frac{1}{2E}\left(\frac{p_z - p_a}{\sqrt{\lambda_z}}\right)^2\right] +$$

$$+ \sqrt{p_a - \frac{1}{2E}\left(\frac{p_z - p_a}{\sqrt{\lambda_z}}\right)^2 + \frac{0{\cdot}1\delta}{1+2\delta}\left(\frac{p_z - p_a}{\sqrt{\lambda_z}}\right)^2 + p_a^2} \quad (10)$$

From this it follows that p_1 can be independent of the thickness (δ) only, if the sum of the first and third terms be constant.

I have calculated the values of P_1 corresponding with different values of δ from the characteristic results given by a certain paper, and this has shown me that the limit of effect, that is to say, the quotient $\left(\frac{p_z}{p_1}\right)$ is almost constant for the papers the thicknes of which is $\delta = 0{\cdot}04 - 0{\cdot}11$ mm.

It is, therefore, probable, that there is in this case a certain definite relation between the number (J) of the double bendings and the internal work.

To enable this relation to be determined, I have put these numbers (J) and the values of A_{kgs}^{mkgs} into a system of logarithmic

coordinates and have obtained a straight line. The formula for this line is:

$$\log J = \cot \varphi \,(\log A_1 - \log A_0)$$

whence

$$J = \left(\frac{A_1}{A_0}\right)^{\cot \varphi} \tag{5}$$

If springs of 1000 grs. be made use of, the relation is:

$$J_{1000} = \left[\frac{A_{kgs}^{mkgs}}{16{\cdot}25}\right]^{2{\cdot}79} \tag{5a}$$

The results calculated by the aid of this formula coincide as well with the classification made by Schopper as this latter does with the classification made by the results of hand treatment.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

V^TH CONGRESS, COPENHAGEN 1909.

X 13

PROPOSAL MADE BY MR. MAYNTZ PETERSEN IN COPENHAGEN ON THE ALTERNATION OF THE METHODS OF TESTING RECOMMENDED BY THE IVth CONGRESS.*

As it was seen at the tests made in the State Laboratory in Copenhagen, that the quantity of 0·40 kg cement — to be used in conformity with the Methods of Testing recommended by the IVth Congress 1906 — is usually too small to fill the metal vessel, so that strucking off of the excess would be possible, it is proposed to limit diameter of the dimensions as follows:

7·5 cm at the base
8·5 cm at the top
4·0 cm deep.

Further it is proposed to replace the vessel by a ring for the purpose of removing more easily the hardened paste, therefore the wording of division c § 3 of the Method of testing hydraulic cements should be running as follows.

"A conical ring, 7·5 cm in diameter at the base, 8·5 cm "at the top and 4 cm deep, is immediately filled with "the paste and the excess is struck off with the trowel, "pressure on the paste and agitation being avoided."

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*) Methods of Testing Metals and Alloys, Hydraulic Cements and Woods, Clay, Stoneware and Cement Pipes. London, E. & F. N. Spon Ltd, New-York, Spon & Chamberlain, 1907.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

XIII4

THE CONSEQUENCES OF THE USE OF MORTAR OF IMPROPER COMPOSITION.

By Prof. **J. A. v. d. Kloes**, Delft.

(Short abstract of the Report to be verbally submitted to the Congress.)
Translated from the German original by A. R. Liddell, Charlottenburg.

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1. The International Association for Testing Materials has done much in the interests of Science and Industry, but comparatively little for Building Construction Practice. The author gladly seizes the opportunity of referring to a subject the neglect of which represents a great economic loss.

2. The efflorescence of masonwork, the wall-rot, and the dampness of buildings all have a common origin: excess of lime in the hydraulic mortar accompanied by a deficiency in the quantity of the sand. These mistakes lead slowly but surely to the destruction of the costliest buildings.

3. It is not right to set trass and Portland cement in juxtaposition to one another as competitors. Each of these has its own special task to perform and can often assist the other in its work in a highly useful manner.

4. The phenomena relating to this matter are so striking, that no unbiassed observer can gainsay them. The author has studied them sufficiently to be able to avoid them with certainty, but the process has not been scientifically established.

It is high time that the "International Association for Testing Materials" included them in the sphere of its operations.

5. Examples of bad work.

6. Rules for the combination of trass with cement mortar.

Poor Lime	Fat Lime	Lime Paste	Trass	Portland Cement	Puzzolana (Trass-Lime) Cement	Sand
a) Mortars which are thoroughly water-proof, and which constantly remain under water.						
1	—	—	$1^1/_4$	—	—	$1^1/_2$
—	1	—	$1^1/_2$	—	—	2
—	—	1	3	—	—	4
—	—	—	—	1	—	2
—	—	—	1	1	—	$2^1/_2$
—	—	—	—	—	1	1
b) Quay and Lock Walls etc.						
1	—	—	$1^1/_4$	—	—	$2-2^1/_2$
—	1	—	$1^1/_2$	—	—	$2^1/_2-3$
—	—	1	3	—	—	5—6
—	—	—	—	1	—	3
—	—	—	1	1	—	4
—	—	—	—	—	1	$1^1/_2$
c) Foundations and Buildings.						
1	—	—	$1^1/_4$	—	—	3—4
—	1	—	$1^1/_2$	—	—	4—5
—	—	1	3	—	—	8—10
—	—	—	—	1	—	3
—	—	—	1	1	—	4—5
—	—	—	—	—	1	3

INTERNATIONAL ASSOCIATION FOR ◻
◻◻◻◻◻ TESTING MATERIALS ◻◻◻◻◻

◻ Vth CONGRESS, COPENHAGEN 1909. ◻

XIII 5

ON THE NEW GERMAN STANDARDS FOR THE UNIFORM DELIVERY AND TESTING OF PORTLAND CEMENT.*)

By Prof. **M. Gary**, Groß-Lichterfelde.
(Translated from the German by A. R. Liddell, Charlottenburg.)

On the 13th of October, 1908, at a specially convened General Meeting in Heidelberg, the Verein Deutscher Portland-zement-Fabrikanten completed the draft proposal for the new German standards, and handed it in to the ministries of the German Confederated States for approval. A special committee for the revision of the standards presided over by Director Dr. Müller, of Rüdersdorf, has in the course of years of work made many thousands of experiments with the object of obtaining reliable bases for this discussion. In addition to the Königliche Material-prüfungsamt zu Groß-Lichterfelde West and the Laboratory of the Verein Deutscher Portlandzement-Fabrikanten, of Karlshorst, a large number of industrial works' laboratories have taken part in the work, and their results, which have been put together in a perspicuous manner by the chairman of the committee, have given a clear picture of the behaviour of Portland cement under different methods of treatment.

The new standards differ from the old ones in three important particulars.

1. The defining conception of Portland cement is supplemented; the chemical composition of the material is thereby taken into account.

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*) Prefatory observations in regard to the communications which the author proposes to make to the Congress.

2. The testing for tensile strength is given up; in its place the requirements of the standard mortar in regard to compression and the degree of fineness of the grinding of the Portland cement are considerably increased.

3. As the properly determining standard test, the compression test on cubes is introduced, which is to extend to bodies of material which have lain for 1 day exposed to the air, and 6 days under water. and have been hardened by 21 days' exposure to the air. As a preliminary trial, the test of cubes after 1 days hardening in moist air and 6 days' immersion in water is introduced.

1. While the conception of Portland cement defined in the old standards regards it as a product „resulting from the burning of an intimately combined mixture composed of lime and argillaceous materials, as principal ingredients, till these form clinker and the subsequent pulverisation of the material to the fineness of flour, the chemical composition of the Portland cement is, in the new standards, set at not less than 1·7 parts by weight of lime to 1 part by weight of soluble silicica + alumina + oxide of iron and the production by means of fine and intimate mixing of the raw products, burning to clinker and grinding finely.

To this flour, when required for special purposes, additions of not more than 3 per cent may be made. The proportion of magnesia may be 5 per cent at most, and that of sulphuric acid anhydride must not exceed $2^1/_2$ per cent.

These decisions remove all doubts as to whether certain cement mixtures may be termed Portland cements or not. On the basis of careful experiments lasting for years, the upper limit for the proportion of magnesia has been fixed at 5 per cent, after it has been established that up to this amount the material cannot produce disintegration in the clinkered Portland cement. In the same way it has been determined by careful experiment, that $2^1/_2$ per cent of anhydride of sulphuric acid may be allowed to pass unchallenged, without disintegration being produced. After specially searching experiments, it has been established beyond doubt that cements with very low percentages of sulphuric acid do not deserve any sort of preference over others in which the percentage of sulphuric acid approaches the higher limit.

2. It being a matter of experience, that it is not possible to draw conclusions from strength-results obtained with Portland

cements without sand-admixture in regard to the faculty of combination with sand, the testing of Portland cement in the mixture with the old well-tried standard sand from Freienwalde is retained, and, since in use the mortar is in the first line subjected to a compressive strain, and the compression strength can be determined with the greatest degree of reliability, the compression tests alone are to be decisive.

From the results of the numerous comparative tests it was established in the "Königliches Materialprüfungsamt in Groß-Lichterfelde", that the reliability of the compression test is considerably greater than that of the tensile test. For a decisive test, however, only the most reliable tests that can be made should be permitted-tests that offer guarantee that, with careful work, concordant results will be obtained even in different places. In view of the reliability thus to be desired, the use of plastically moulded samples, such as have been recommended in several quarters, has been decided against. The old ramming method, with the Böhme hammer, which has for years proved satisfactory in Germany, has been retained.

According to the new standards, Portland cement is to be ground so finely, that it only leaves a residue of 5 per cent on a sieve of 900 meshes to the cm^2. The width of mesh of the sieve is to be 0.222 mm.

Slow setting Portland cement with 3 parts by weight of standard sand to one of cement shall, after 7 days hardening, 1 day in moist air and 6 days under water, attain a compressive strength of at least 120 kg per cm^2; after a further hardening for 21 days in air of 15—30 C., the compressive strength must be at least 250 kg per cm^2. In cases of contention only the test after 28 days is to be applied.

Portland cement that is intended for hydraulic engineering structures shall, after 28 days hardening, 1 day in moist air and 27 days under water, show a compressive strength of at least 200 kg per cm^2.

In the case of quick-setting Portland cements, the strength after 28 days is, in general, less than that given above. When, therefore, strength values are quoted, the time of setting is always to be mentioned as well.

3. It was a matter of conviction, that, especially for the comparison of several cements with one another, the test with a

high proportion of sand was absolutely necessary; as a standard proportion, 3 parts by weight of sand to 1 part cement was adopted. When, however, the useful work to be obtained from a Portland cement is to be determined, series of tests with a higher proportion of sand were recommended.

The testing method agreed upon on the so-called combined hardening method (1 day air, 6 days water, 21 days air) is accommodated to the conditions of everyday practice, since by far the largest proportion of Portland cement is used for building purposes. This system of testing was taken up as the outcome of many thousands of tests in the Königliches Materialprüfungsamt, where it was established, by means of curves of frequency of the new and old water-hardening methods, that either could be used with equally reliable results. All endeavours to discover a reliable method of testing for pure air-hardening have proved fruitless. It has become apparent, that warmth and moisture of the air and other local peculiarities influence the test results obtained by air-hardening to such a degree that concordant values at different places cannot be obtained, The old Prussian standards came into force on July 28th. 1887. They have served the German Portland cement industry as a guide for more than 20 years, and have been imitated in many civilized countries. It is to be expected that the new standards will perform their part in a still higher degree than the old ones in promoting the development of the industry and it would be in a high degree desirable, that other countries should join in the advance made by the German industry and make the highest possible requirements on the reliability of the testing methods.

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XIX 1

ON TESTING AS APPLIED TO AUTOMOBILES.

By **Dr. W. Exner,** Vienna.*)

Communications in regard to existing testing establishments of this kind and their results.

Programme for a state testing establishment for power vehicles.

Conditions of competition for the Pötting prize for the creation of methods for the testing of cycle wheel tyres.

Invitation for the submission of proposals for speed-limitation devices.

XIX 2

ON THE INTERNATIONAL REGULATION-BY-LAW OF TECHNICAL TESTING.

By **Dr. W. Exner,** Vienna.*)

Review of the older and more recent laws which bear upon particular branches of testing, such, for instance, as those relating to Gauging, Stamping, Portable Firearms, Adulteration of Food, Steam Boilers, Automobile-Responsibility, Duties on Articles of Consumption, etc.

Legal definition of the nature of the certificates to be issued as public documents by the experimenting, investigating, testing, and experimental-trial conducting establishments.

Regulations in the form of ministerial decrees relating to technical testing.

Origin of the Austrian law (Lex Exner), relating to investigating, experimenting, and testing establishments, and proposals for an extension of the mentioned law by an international agreement.

*) Outlines of a report to be verbally given at the Congress.

XX

BUSINESS REPORT FOR THE PERIOD FROM THE IVth TO THE Vth CONGRESS.

The Council, elected for the period from the IVth until the Vth Congress, was formed at the Meeting held at Munich on Feb 11th 1907. Its first resolution was the nomination of Dr. Franz Berger of Vienna as permanent member of the Council. The Council hoped by this honouring Dr. Berger, to express their thanks for his activity as well as to secure his further cooperation. The former Vice-presidents, Dr. A. Martens of Groß-Lichterfelde and Dr. N. Belelubsky Exc. of St. Petersburg, were unanimously re-elected.

The present list of the Council (Appendix A) is somewhat different from that drawn up at the IVth Congress.

By the death in October 1908 of Mr. Bennett H. Brough, Representative for Great Britain, the Association has experienced a most painful loss. Mr. Brough had succeeded in promoting the objects and interests of the Association in Great Britain, where their principles of unification had met with much opposition. His name will remain inseparably connected with the development of the Association. He has been replaced by Mr. G. C. Lloyd, Secretary to the Iron and Steel Institute, elected by British Members.

Mr. J. O. Roos of Hjelmsäter of Stockholm had willingly consented to act until the new elections in the place of Mr. G. Dillner, who has been prevented owing to great pressure of work.

A new country, Luxemburg, is now being represented in the Council, and Mr. E. Bian, Director of the Forges d'Eich in Dommeldingen, has kindly untertaken the functions of a mandatory.

The resolution of the IVth Congress to elect a General Secretary has been carried out by the Council, through the nomination to that post of Mr. Ernst Reitler, former Secretary, whose extended sphere of activity has been defined in a Contract and in the Council rules. By the appointment of a General Secretary, who carries on the businees of the Association according to the directions of the President,, stability and continuity in its management are secured.

The Council assembled at Munich on the 11th and 12th Feb. 1907 for the XVIth Meeting since the foundation of the Association, on the 11th April 1908 at Munich for the XVIIth, and on the 6th Feb. 1909 at Frankfort on Main for the XVIIIth.

Their principal task was to make provision for the working plan of the Vth Congress, based on the resolutions of the IVth.

A suggestion made by Professor H. Le Chatelier in a letter, addressed to Professor H. I. Hannover at Copenhagen, was successfully turned to account in the resolutions of the Council. Mr. Le Chatelier had recommended, that provision be made for interesting discussions of the Sections of the next Congress, by proposing only a few important questions of universal interest for discussion. These subjects should induce parallel studies in different countries with mutual communications between the referees. Professor Le Chatelier, suggested as useful questions, the irregularity in the tests of strength of cements and mortars, and the remedying of the same, the resistance of metals under alternating stresses, the influence of high temperature on the mechanical properties of metals, and Brinell's ball pressure tests of hardness.

These proposals met with full approval on the part of the Council, and by the proposition of several Principal Questions which are of vital interest at the present day, starting points were given for discussion at the next Congress. For these Principal Questions contributions from the members of all countries were solicited, and distinguished experts were invited to give a general review of the state of the respective subject as official referees and personally to introduce the discussion at the Congress.

The Principal Questions and the referees appointed by reason of the proposals of members of the Council or National Societies are as follows:

A. Metals.

Metallography (Metallurgy, Alloys). Referee H. Professor E. Heyn, Groß-Lichterfelde.

Hardness testing, Referee H. Dr. P. Ludwik, Vienna.

Impact tests, Referee H. G. Charpy, Paris.

Testing metals by alternating stresses (Referee H. E. J. Howard, Watertown Arsenal.

Testing of cast iron, Referee H. Dr. R. Moldenke, New-York.

Influence of increased temperature on the mechanical qualities of metals, Referee H. Professor M. Rudeloff, Groß-Lichterfelde.

B. Cement, Stones, Concrete etc.

Reinforced Concrete, Referee H. Professor J. Schüle, Zurich.

Progress in the methods of testing cement, Referee H. R. Feret, Boulogne-sur-mer.

Cement in sea water, Referees H. W. Czarnomski and A. Baykoff, St. Petersburg.

Weathering resistance of building-stones, Referee H. Professor A. Hanisch, Vienna.

C. Miscellaneous.

Oils, Referee H. Dr. M. Albrecht, Hamburg.

Caoutchouc, Referee H. E. Camerman, Brussels.

Wood, Referee H. K. W. Hatt, Lafayette, Ind.

Paints on metallic structures, Referees H. Prof. E. Heyn, Groß-Lichterfelde, and H. S. S. Voorhees, Washington.

The proposition of the principal questions had the desired result, that a series of problems in testing materials in which interest centres at the present day have been dealt with independently of one another by competent experts of all countries. These monographs and the above official reports will form the basis of the discussions at the Congress. Thus a new international procedure of dealing with certain problems has been formed, in place of the rather arduous task devolving on the Committees; at the same time, important lines of thought

were thereby given by which discussion could be successfully at the Vth Congress.

If the Council even justly anticipated any special result from the individual treatment of these questions, or parts of the same, it was an understood thing, that certain problems could still only be successfully treated by Committees in the same manner as hitherto. Such problems are those which aim at unification of testing methods or which in other directions touch on extensive spheres of interest everywhere, and in order to work them out, it is necessary that the referees should keep in touch with the influential circles of the various countries.

A series of Committees might be invited to continue their work, with reference to the decision of the Congress. These Committees would deal with the following technical problems:

1. International specifications for iron and steel for the drawing up of which a Sub-Committee of six members, from Great Britain, the United States of America and Germany, has been appointed (see Appendix B).

2. Investigation as to the homogeneity of iron and steel for purposes of acceptance.

25. Cast iron.

24. Uniform nomenclature of iron and steel.

9. Rapid determining of strength of cements.

11. Tests of Pouzzolanas in view of their value for the mortars.

7. Weathering qualities of stones.

32. Consistency of volume.

34. Nomenclature of bitumen.

Likewise the Hungarian Association for reporting on the technical tasks.

33. Influence of water and sand proportions on the strength of Roman Cement.

To these were added, by reason of the decision of the Congress, the new Committees, the list of which is to be found in Appendix B, appointed to deal with the following problems:

38. Specifications for copper.

30. Finest particles in Portland cement.

41. Reinforced concrete.

42. Tests of cement with prisms and standard sands.

39. Oils.

Lastly the appointment of referees for the problems as follows.

28. The magnetic and electric properties of metals in connection with their mechanical testing.

40. Specifications for gypsum.

The remaining problems on the list of the Association: 4. Welding, 6. Polishing and etching for microscopic structure tests, 26. Notched bar tests, 27. Ball pressure tests, 36—37. Macroscopic and microscopic structure investigations, 10. Adhesive qualities of hydraulic cements, 12. Time of setting, 31. Cement in seawater, could remain without special referees, their dealing with being secured by their belonging to the principal questions.

The result of the lively participation of numerous referees in these principal questions, and the great activity of the Committees that have partly brought to their conclusion or have at least advanced considerably a series of important problems in a manner worthy of thanks, is evident in the list given in Appendix C of the Reports, laid before the Congress. This list conveys an idea at the same time of the intense and many sided work, which is now-a-days devoted to the testing of materials in all civilised countries of the world.

Besides the organising work of the Congress, the Council has devoted special care to the **question of publication.**

The resolutions of the Bauschinger Conferences of the year 1893 were the last results of international co-operation in the sphere of the testing of materials. By the publication of the "Methods of testing Metals and Alloys, Hydraulic Cements and Woods, Clay, Stoneware and Cement Pipes" recommended by the IV^{the} Congress which was placed on sale in three languages in London and New-York, Leipsic, Vienna and Paris, the work undertaken by the Conferences was at length considerably furthered. By the publication of the last "Congress Proceedings" and of the report by Guillet, on the Model Laboratory, exhibited at Brussels, which showed modern methods of testing in their practical uses, but above all by the introduction of an official organ in three languages, viz the "Proceedings", the Council has kept all members informed of all the works of the Association, and by the publicity gained by the sale of this organ, has won new adherents and co-operators to the ideas of the Association.

In the "Proceedings" the Council have tried to create a literary centre for all efforts in the branch of the study of materials. Besides the business communications of the Association, the "Proceedings" will publish all Congress Papers and Congress discussions and a continual index of all publications in this branch, particularly in the sphere of experience and experiments and in a more complete manner than in any other excellent publication of this kind. In the working out of this index, the Council hope to gain in time the co-operation of all Laboratories in the world, in such a manner, as to place at their disposal a notice of their work in one of the three official languages.

The great advantages which the Council endeavoured to offer all members of the Association, by sending them gratis all the Congress papers in one of the three official languages, placed a greater strain on the finance of the Association than its somewhat limited resources were able to bear. At the Brussels Congress, and at the present one in Copenhagen, it was only through the generosity of the Organising Committee, that this difficulty was overcome in a manner worthy of thanks.

Under these circumstances the Council could not avoid acknow ledging, that in the near future fresh resources must be thought of, in order to continue safely and successfully in the same way as heretofore.

Receipts and Expenditures of the Head Cash Office (Francs)
(S. Financial Returns, Appendix D)

	1906		1907		1908	
	Receipts	Expenditures	Receipts	Expenditures	Receipts	Expenditures
Cash in hand on January 1st . . .	11.892·66		200·97		1.731·27	
Ordinary receipts and expenditures .	14.536·45	9.678·02	14.003·86	9.741·25	14.272 62	10.951·55
Extraordinary receipts and expenditures	17.489·46	34.039·58	5.261·55	7.993·86	68·33	1.806·90
(Subvention of the Organising, Committee in Brussels, Publishing the Congress Papers, Sundries.)						
Balance		200 97		1.731·27		3.313·77
Total . .	43.918·57	43.918·57	19.466·38	19.466·38	16.072·22	16.072·22

The great success of the Brussels Congress, and the prospective scientific work of the coming one, which have been made known by the „Proceedings“ to wider circles, have occasioned a satisfactory increase of members in almost all countries. Sine c 1906 the number of members has increased from 1906 to 2300. (S. Appendix E.) Thelist of the Societies and Public Bodies subventioning the Association, with a total contribution of 4420 frcs. which forms about the fourth part of the regular income of the Association — also shows an increase — even though small. (S. Appendix F.)

We regret to announce that the Association has sustained many a heavy loss in the ranks of its members in the period of time that has now elapsed.

Besides the death of Mr. Bennett H. Brough, the much esteemed member of the Council for Great Britain, already mentioned, the Association also deplores the loss of Mr. J. Magery, and Mr. E. Roussel, who as Presidents of Sections at the last Congress, contributed to its success by their distinguished merits. By the death of Dr. H. Giessler the Association lost the indefatigable publisher of the Journal „Baumaterialienkunde“, who for 12 years had formed a literary centre for the study of materials, and in whose journal the official communications of the Association were to be found. The loss of such men, as Julius Thompsen who would have contributed the lustre of his name to the Copenhagen Congress, of G. Cartaud and H. Wedding, has been mourned by the whole scientifie world.

The following list shows the names of those men who belonged tho the Association as distinguished co-operators and faithful members, and who have passed away since the last Congress.

Böcking F., Oberingenieur, Düsseldorf.

Gießler, H., Dr., Professor, Herausgeber der Baumaterialienkunde, Stuttgart.

Kintzlé F., Betriebsdirektor, Rote Erde bei Aachen.

Peters Dr. Ing., Geheimer Baurat, Berlin.

Wedding H., Dr., Professor, Geheimer Bergrat, Berlin.

Kernot W. C., M. A. S. C. E., Melbourne.

Rudschitzky C., Ingenieur, Witkowitz.

Acker Paul, Ingenieur en chef de Service de la Société John Cockerill, Seraing.

Coiseau Louis, Ingénieur Civil, Entrepreneur à Paris.

Frenay Henri, Ingénieur, Directeur général de la Fabrique Nationale d'armes de Guerre à Herstal, Liège.

Magéry Jules, Administrateur des Aciéries Rote Erde, Aachen à Namur.

Roussel Ernest, Ingénieur, Directeur de l'Arsenal des Chemins de fer de l'Etat Belge à Malines.

Teller C. Ph., Professor der techn. Hochschule, Hellerup.

Bayer, Sous-Chef du Service des Approvisionnements aux chemins de fer de l'Etat.

Cartaud G., Ingénieur chimiste, Boulogne s. Seine.

Lejeune, Ingénieur au Service du Laboratoire et des Etudes de la Société J. et A. Pavin, Lafarge.

Polonceau (R.), Ingénieur au Service du Matériel et de la Traction de la Compagnie des chemins de fer d'Orléans.

Quinette de Rochemont, Inspecteur général des Ponts et Chaussées en retraite.

Rouzet, Fabricant de ciment à Tours.

Blackwell G. G., Liverpool.

Brough Bennett H., Secretary to the Iron and Steel Institute London.

Spencer J., W., Newcastle on Tyne.

Gray Thomas, Professor of Dynamic Engineer, Rose Polytechnic Institute, Terre Haute, Ind.

Leproux André, Directeur Général de la Compagnie Royale du chemin de fer Portugais, Lisbonne.

Juzarte Caldeira, Carlo Augusto, Colonel d'Artillerie, Directeur de la Manufacture d'armes de l'Etat, Lisbonne.

Perraudin A., Oberingenieur, Huta Bankowa (Russie).

Lindberg Werner, Senator, Helsingfors.

Strömberg G., Wirklicher Staatsrat, Helsingfors.

Gugler K., Ingenieur, Zürich.

Ritter W., Dr., Professor, Zürich.

A glance at the period that has now elapsed shows us that a deeper sense of the importance of the testing of materials has

taken ground in all countries, and with this increasing acknowledgment, the importance of the International Association has also risen step by step. The foundation and the rapid development of the National Societies Italy, Austria, and Russia, which have occurred during this period, is the best proof for the vital energy, and the inward justification of ideas which the Association represents. With the same self-sacrifice, as was shown by the small circle assembled round Bauschinger, the Association of to-day, comprising as it does, all civilised countries, pursues its endeavours with a tendency to the unification and development of testing methods, and the more powerfully these ideas strike root in individual countries, the greater is the profit which accrues from the co-operation of all factors in the International Association all concerned.

In the name of the Council:

Ernst Reitler,
General-Secretary.

Alex Foss,
President.

Appendices A—F.

MEMBERS OF COUNCIL, AUGUST 1909.

Permanent Member:

Franz Berger, Dr. techn., k. k. Sektionschef im Ministerium für öffentliche Arbeiten, Stadtbaudirektor a. D., Wien.

Council elected for the Period from the IV[th] to the V[th] Congress.

President:

Alex. Foß, Engineer, Machine-manufacturer of Copenhagen.

Vice-Presidents:

A. Martens, Dr. Ing., Professor, Geh. Ober-Reg.-Rat, Mitglied der kgl. Akademie der Wissenschaften zu Berlin, Direktor des kgl. Materialprüfungsamtes in Gr.-Lichterfelde.

N. Belelubsky, Dr. Ing., Exc., conseiller privé, prof. em., membre du conseil du génie au Ministère des voies de comm., directeur du Labor. méc. de l'Institut imp. des voies de comm., St. Pétersbourg.

Council-Members:

Austria: **B. Kirsch**, k. k. o. ö. Professor und Vorstand des mech.-techn. Laboratoriums der technischen Hochschule, Wien.

Belgium: **A. Greiner**, directeur général de la Société John Cockerill, Seraing.

Denmark: **H. I. Hannover**, Professor and Director of the Royal Government Testing Laboratory, Copenhagen.

France: **A. Mesnager**, ingénieur en chef des ponts et chaussées, professeur et directeur des Laboratoires à l'Ecole des ponts et chaussées, Paris.

Germany: **A. Martens**, see above.

Great Britain: **G. C. Lloyd**, Secretary to the Iron and Steel Institute, London.

Holland: **L. Bienfait**, Engineer, Co-proprietor of the Testing-Laboratory Koning & Bienfait, Amsterdam.

Hungary: **C. v. Banovits**, Former Director of the R. State Railways, Budapest.

Italy: **J. Benetti**, ingénieur, professeur et directeur de l'École R. d'application pour les ingénieurs, Bologna.

Norway: **S. A. Lund**, Head Engineer of the Norwegian State Railways, Christiania.

Roumania: **M. C. Mironesco,** inspecteur général, directeur de l'École des ponts et chaussées, Bucarest.

Russia: **N. Belelubsky,** Exc. see above.

Spain: **J. Marvà y Mayer,** général du génie, Chef de Section au Ministère de la Guerre, de l'Académie Royale des Sciences exactes, physiques et naturelles, Madrid.

Sweden: **J. O. Roos af Hjelmsäter,** Director of the Royal Testing Laboratory, acting for the elected member **Gunnar Dillner**, Stockholm.

Switzerland: **F. Schüle**, Professor am eidgen. Polytechnikum, Direktor der eidgen. Materialprüfungsanstalt in Zürich.

United States of America: **Chas. B. Dudley,** Chemist, Pennsylvania Railroad, Altoona, Pa.

Mandataries:

Australia: **W. H. Warren,** M. Inst. C. E., M. Am. Soc. C. E., Challis Professor of Engineering, University of Sydney.

Finland: **A. Granfelt**, Director of the State Railways, Helsingfors.

Luxenburg: **E. Brian**, Directeur des Usines de Dommeldange et des Forges d'Eich, Dommeldange.

Portugal: **J. da P. Castanheiro das Neves**, ingénieur, directeur des études et essais des matériaux de constrution, Lisbonne.

Servia: **M. Milašinovic**, Former Vice-director of the R. State Railways of Servia, Belgrad.

COMMITTEES AND REFEREES APPOINTED SINCE THE IVth CONGRESS FOR STUDYING TECHNICAL PROBLEMS.

Problem 1.

Establishment of International Specifications for Iron and Steel.

Subcommittee 1a.

Chairman: v. Rieppel, Chairman of Committee 1.

Representatives of Germany:

Professor R. Stribeck, Essen-Ruhr; Direktor H. Vehling, Aachener Hüttenverein, Rote Erde bei Aachen.

Representatives of Great Britain:

F. W. Harbord, London; F. E. Robertson, London.

Representatives of the United States of North America:

Wm. R. Webster, Philadelphia, Penna; W. Wood, Philadelphia, Penna.

Problem 28.

The Utilisation of the Magnetic and Electric Properties of Metals in conducting Mechanical Tests.

Referees: A. Grünhut and Dr. J. Wahn, Vienna, Prof. Dr. Pierre Weiss, Zürich, E. Rasch, Groß-Lichterfelde, J. W. Esterline, Lafayette.

Problem 38.

The principles for specifications of copper are to be studied.

(Proposed at the Brussels Congress 1906.)

Chairman of the Commission: Léon Guillet, Paris.

Members: C. Heckmann, Duisburg-Hochfeld; G. Selve, Altena i. W. (Germany); R. T. Glazebrook, Teddington near London; F. Tomlinson, Manchester; G. Guillemin, Paris;

P. Breuil, Paris; Olgouine, Moscou; E. Wehrenfennig, Vienna, Zugmayer jun., Waldegg (N.-Österreich); G. E. Skinner, East Pittsburg; H. E. Diller, Chicago.

Problem 30.

Determination of the simplest method for the separation of the finest particles in Portland cement by liquid and air process. (Proposed at the Budapest Congress 1901.)

Chairman of the Commission: M. Gary, Gr.-Lichterfelde.

Members: A. Dyckerhoff, Biberich a. Rh.; K. G. Bamber, London; A Mesnager, Paris; R. Feret, Boulogne s/M.; Mayntz-Petersen, Copenhagen; Eidgenössische Materialprüfungs-Anstalt (Laboratory for Testing Materials), Zurich.

Problem 40.

Study of the unification of specifications for gypsum. (Proposed at the Brussels Congress 1906.)

Referees: Prof. Max Gary, Gr.-Lichterfelde; R. Feret, Boulogne-sur-mer.

Problem 41.

Investigations of reinforced concrete. (Proposed at the Brussels Congress 1906.)

Chairman of the Commission; Prof. F. Schüle*), Zurich.

Vice-Chairmen: W. Germelmann, Berlin; Prof. A. N. Talbot, Urbana, Ill.

Members: W. H. Warren, Sydney; Paul Christoph, Brussels; E. Suenson, Copenhagen; T. Grut, Copenhagen; Alf. Hüser, Oberkassel (Germany); E. Züblin, Straßburg i. E. Germany); A. Martens, Gr.-Lichterfelde; Bürstenbinder, Hamburg; Edwin O. Sachs, London; Max Clarke, London; W. Dunn, London; Prof. C. W. Unwin, London; A. Considère, Paris; Ch. Rabut, Paris; A. Mesnager, Paris; R. Feret, Boulogne; M. Tricon, Paris; S. J. Rutgers, Rotterdam; Silvio Canevazzi, Bologna; Camillo Guidi, Turin; Claudio Segré, Rome; R. Norwegien Road-Department in Christiania; V. Brausewetter, Vienna; J. Melan, Prague; B. Kirsch, Vienna; F. v. Emperger, Vienna; N. Belelubsky, St. Petersburg; Droujinine, St. Petersburg;

*) Mr. A. Considère having resigned his functions.

Boguslawsky, St. Petersburg; Abramoff, St. Petersburg; R. Maillart, Zurich; Richard Zielinski (Szilard), Budapest; Josef Schustler, Budapest; A. Czakó, Budapest; E. Turneaure, Wisconsin.

Problem 42.

Uniform tests of hydraulic cements by prisms and determination of a standard sand. (Proposed ad the Brussels Congress 1906.)

Chairman of the Commission: F. Schüle, Zurich.

Members: Laboratoire des Ponts et Chaussées, Boulognes s/M. (R. Feret); Laboratoire des Ponts et Chaussées, Paris (A. Mesnager, Mercier); Laboratoire du Conservatoire des Arts et Métiers, Paris (Leduc); Kgl. Material - Prüfungsamt, Gr.-Lichterfelde (A. Martens, M. Gary); Laboratorium des Vereines deutscher Portland-Zementfabrikanten, Karlshorst bei Berlin (Framm); Eidgenössische Material-Prüfungsanstalt, Zurich (Schüle); Laboratoire méc. de l'Institut Imp. des voies de comm., St. Petersburg (N. Belelubsky, Bogdansky); Mechanisch-technisches Laboratorium der technischen Hochschule, Wien (B. Kirsch); Danist. Government Testing Laboratoy in Copenhagen (Mayntz-Petersen); Ecole d'applications pour le Ingeniéurs, Bologna (S. Canevazzi); Laboratoire de l'Arsenal de l'Etat Belge. Malines (E. Camerman); Material - Prüfungsanstalt von Bienfait & Koning, Amsterdam (L. Bienfait); Materials Testing Laboratory United States Geological Survey (Rich. L. Humphrey), Philadelphia, Pa.

Problem 39.

Study of the principles of specifications of oil for technical purposes. (Proposed at the Brussels Congress 1906.)

Chairman of the Commission: M. Albrecht, Hamburg.

Vice-Chairman: E. Camerman, Malines (Belgium).

Members: A. Jakobsen, Copenhagen; Holde, Gr.-Lichterfelde; Havald Buch, Christiania; R. T. Glazebrook, Teddington near London; P. Breuil, Paris; H. Baucke, Amsterdam; H. Cattaneo, Rome; J. Großmann, Wien; R. Kind, Aussig a. E. (Austria); Gebrüder Sulzer, Winterthur; A. H. Gill, Boston; H. A. Julius, Midland Junction, Western Australia.

PAPERS PRESENTED TO THE VTH CONGRESS FOR TESTING MATERIALS IN COPENHAGEN.

A. METALS.

Metallography.

I 1 **Report on Progress made in Metallography from the Brussels Congress up to the Commencement of 1909.** By Prof. **E. Heyn**, Groß-Lichterfelde.
I 2 **Special Steels.** By Prof. **Léon Guillet**, Paris.
I 3 **The Heat Treatment of Spring Steel.** By **Lawford H. Fry**, Paris.
I 4 **"Slag Enclosures" in Steel.** By **Walter Rosenhain**, B. A., D. Sc., Teddington.

Hardness Testing.

II 1 **Hardness Test.** Official report by Dr. **P. Ludwik**, of Vienna.
II 2 **Simplified Ball-Hardness Testing Machine and Results obtained therewith.** By Prof. **A. Martens** and **E. Heyn**, Gr.-Lichterfelde W.
II 3 **The Cone-Pressure Test for Determining the Hardness of Permanent Way Materials.** By Dr. **August Geßner**, Vienna.
II 4 **Investigations on the Brinell Method of determining Hardness.** By **Harold Moore**, B. Sc., Woolwich Arsenal, England.

Impact Tests.

III 1 **Official Report on Impact Tests of Metals.** By **G. Charpy**, Montluçon.
III 2 **On Notched-Bar Impact Bending Tests.** By Prof. **F. Schüle**, in conjunction with **Ed. Brunner**, of Zürich.
III 3 **The Definition of Resilience in Impact Tests.** By **Louis Révillon**, Paris.
III 4 **Impact Tests at variable Temperatures.** By Prof. **Léon Guillet** and **Louis Révillon**, Paris.
III 5 **Impact Tensile Tests.** By **Pierre Breuil**, Paris.
III 6 **Application of Modern Testing Methods to Copper Alloys.** By Prof. **Léon Guillet** and **Louis Révillon**, Paris.
III 7 **Comparative Static and Dynamic Notched-Bar Bending Tests.** By Dr. **A. Leon** and Dr. **P. Ludwik**, Vienna.
III 8 **Note on the Rupture of Normal Cylindrical Test Samples by Longitudinal Impact.** By **P. Wélikhow**, Moscow.
III 9 **On Piece Tests of Important Structural Parts.** By **O. Hönigsberg**, Vienna.

Testing Metals by Alternating Stresses.

IV 1 **The Endurance of Steels to Repeated Alternate Stresses.** By **James E. Howard**, Watertown, Mass., U. S. A.
IV 2 **Quality Tests and Endurance Tests of Copper Wires.** By Prof. **F. Schüle** and **E. Brunner**, Zürich.

Testing of Cast Iron.

V 1 **Report in connection with the Tables of Results of Experiments on the Strength-Properties of Cast-Iron of various Sections taken from separately-cast samples and from samples cut out of castings.** By **Brothers Sulzer**, Winterthur, Switzerland.

Influence of Increased Temperature on the Mechanical Qualities of Metals.

VI 1 **Official Report** by Prof. **M. Rudeloff,** Groß-Lichterfelde W.

Magnetic and Electric Properties of Materials in Connection with their Mechanical Testing.

VII 1 **The Utilisation of the Magnetic and Electric Properties of Materials in conducting Mechanical Tests.** Report by **A. Grünhut** and Dr. **J. Wahn,** Vienna.

VII 2 **Ferromagnetism and the Study of Metals and Alloys.** By Prof. **Pierre Weiss,** Zürich.

VII 3 **Method for Determinig Elastic Strength Limit by Means of Thermoelectric Measurements.** By **Ew. Rasch,** Gr.-Lichterfelde.

VII 4 **Report** by Prof. **J. W. Esterline,** Lafayette.

Committees' Reports.

VIII 1 **Establishment of International Specifications for Iron and Steel.** Report of the Subcommittee Ia presented by the chairman of Committee I, Dr. Ing. **A. Rieppel,** Nürnberg.

VIII 2 **On the Uniform Nomenclature of Iron and Steel.** Report of Committee 24. Presented by Prof. **Henry M. Howe,** Chairman, New York, and Prof. **Albert Sauveur,** Secretary, Cambridge, Mass.

VIII 3 **On Standard Specifications for the Purchase of Copper.** Report of the Copper Committee 38, by the Chairman Mr. **Léon Guillet,** Paris.

Various reports.

VIII 4 **A New Mirror Apparatus for Measurements of Elasticity.** By Professor **B. Kirsch,** Vienna.

VIII 5 Not appeared.

VIII 6 **Unification of Methods for Testing Steam, Gas and Water Pipes.** By **A. C. Karsten,** Copenhagen.

VIII 7 **Sparks as Indications of the Different Kinds of Steel.** By **Max Bermann,** Budapest.

Internal Strains.

VIII 8 **On the Principles of "Technological Mechanics".** By Dr. **Paul Ludwik,** Vienna.

VIII 9 **Internal Friction in Loaded Materials.** By **G. H. Gulliver,** B. Sc., Edinburgh.

VIII 10 **On irregular Strains due to Nonhomogeneity of Materials.** By Dr. techn. **A. Leon,** Vienna.

VIII 11 **Connection between the Permanent Sets caused by Traction and Compression.** By Dr. **William Misángyi,** Budapest.

VIII 12 **Tenacity and Malleability.** By Dr. **William Misángyi,** Budapest.

B. CEMENT, STONES, CONCRETE.

Reinforced Concrete.

IX 1 **Report of the Committee on Reinforced Concrete.** Presented by the Chairman of Committee No. 41, Prof. **F. Schüle,** Zurich, with the following appendices.

a) **Wissenschaftliche Versuche und Versuche zur Kontrolle der Bauausführung auf dem Gebiete des Eisenbetonbaues in Deutschland.** Mitgeteilt vom Deutschen Ausschuß für Eisenbeton, Berlin.

b) **Expériences et essais de contrôle sur le béton armé en Italie.** Rapport de M. le prof. **J. Benetti,** Bologne.

c) **Eisenbetonversuche in Dänemark.** Mitgeteilt von Prof. **E. Suenson,** Kopenhagen.

Progress in the Methods of Testing.

Cement in Sea Water.

Weathering Resistance of Building Stones.

Various Reports.

XIII 1 **The Bonding of Layers of Mortar after Different Time Intervals.** By Prof. **B. Kirsch**, Vienna.
XIII 2 **Notes on Trass, Trass-Cement and Cement-Lime mortars.** By Dr. techn. **Heinrich Renezeder**, Vienna.
XIII 3 **Contribution to Methods of Investigation into the Elastic Longitudinal Deformation of Concrete.** By Dr. **B. v. Bresztowsky**, Budapest.
XIII 4 **The Consequences of the Use of Mortair of Improper Composition.** By Prof. **J. A. v. d. Kloes**, Delft.*)
XIII 5 **On the new German Standards for the Uniform Delivery and Testing of Portland-Cement.** By **M. Gary**, Gr.-Lichterfelde.*)
XIII 6 **On the Specific Heat of Refractory Materials at High Temperatures.** By **J. W. Mellor**, Stoke-on-Trent.

C. SUNDRIES.

Oils.

XIV 1 **Official Report** by Dr. **M. Albrecht**, Hamburg.

Caoutchouc.

XV **Methods of Testing Caoutchouc.** By **E. Camerman**, Brussels
XV 1 **Mechanical Testing of Caoutchouc.** By **P. Breuil**, Paris.
XV 2 **Contribution to the Question of the Mechanical Testing of Soft Rubber.** By **K. Memmler** and **A. Schob**, Gr.-Lichterfelde W.

Wood.

XVI 1 **Abstract of Report on the Present Status of Timber Tests in the Forest Service, United States Department of Agriculture.** By Prof. **William Kendrick Hatt**, Lafayette, Ind., U. S. A.

Paints on Metallic Structures.

XVII 1 **On the Corrosion of Iron in Water and Aqueous Solutions.** By Prof. **E. Heyn** and Prof. **O. Bauer**, Gr.-Lichterfelde.
XVII 2 **On Preservative Coatings for Iron and Steel. Résumé of Work done by the American Society for Testing Materials.** Presented by **S. S. Voorhees**, Washington D. C.
XVII 3 **A Study of Rust-Preventing Paints for Metal Structures.** By **Em. Camerman**, Brussels.
XVII 4 **A Plea for International Investigation concerning Protective Coatings for Iron and Steel.** By **J. Cruickshank Smith**, B. Sc., London.

Papers.

XVIII 1 **On repeated stresses on papers.** By Prof. **A. Rejtő**, Budapest.

General Matters.

XIX 1 **Testing in the Domain of Automobile Work.** By Dr. **W. Exner**, Vienna.*)
XIX 2 **On the international Regulation-By-Law of Technical Testing.** By Dr. **W. Exner**, Vienna.*)

*) Short abstract of the Report to be verbally submitted.

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NS FOR THE YEARS
AND 1908.

Table I.

Total-Receipts and Expenditures of the Association according to Table II and III.

Receipts	1906		1907		1908	
	detailed	total	detailed	total	detailed	total
	Francs		Francs		Francs	
I. Cash in hand on 1st January:						
a) Head cash office	11.892 66		200·97		1.731·27	
b) In hands of Delegates	1.546·75		718·68		1.070·58	
		13.439·41		919·65		2.801·85
II. Total receipts:						
a) through the Delegates and Mandataries	16.112·48		16.984·14		16.904·64	
b) Regular subscriptions and subventions sent in direct to the Head cash office	1.108·05		266·02		274·28	
c) Extraordinary subventions and receipts of the Head cash office	17.489·46		5.261·55		68·33	
		34.709·99		22.511·71		17.247·25
Total . .	—	48.149·40	—	23.431·36	—	20.049·10

Expenditures	1906		1907		1908	
	detailed	total	detailed	total	detailed	total
	Francs		Francs		Francs	
I. Total-Expenditures						
a) Head cash office see table II . .	43.717·60		17.735·11		12.758·45	
b) Delegates and Mandataries see table III	3.512·15		2.894·40		2.394·73	
		47.229·75		20.629·51		15.153·18
II. Cash in hand on 31st December						
a) Head cash office	200·97		1.731·27		3.313·77	
b) Delegates and Mandataries . .	718·68		1.070·58		1.582·15	
		919·65		2.801·85		4.895·92
Total . .	—	48.149·40	—	23.431·36	—	20.049·10

NS FOR THE YEARS
AND 1908.

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Receipts and Expenditures of the Delegates and Mandataries.

Country	1906					1907					1908					
	Balance January 1st	Receipts from Members subscriptions and subventions	Total	Paid to the Head Cash Office	Expenditures	Balance January 1st	Receipts from Members subscriptions and subventions	Total	Paid to the Head Cash Office	Expenditures	Balance January 1st	Receipts from Members subscriptions and subventions	Total	Paid to the Head Cash Office	Expenditures	Cash in hand 31st December
	Francs					Francs					Francs					
Australia	—·—	—·—	—·—	—·—	—·—	—·—	45·28	45·28	45·28	—·—	—·—	157 50	157·50	157·50	—·—	—·—
Belgium	—·—	482·30	482·30	480·30	2·—	—·—	615·—	615·—	581·50	33·50	—·—	562·50	562·50	553·—	9·50	—·—
Denmark	—·—	405·—	405·—	333·82	111·96	— 40·78	495·53	454·75	375·86	35·46	43·43	653·19	696·62	574·56	44·59	77·47
Germany	925·90	4.025·44	4.591·34	3.375·—	1022·71	553·63	4.234·12	4.787·75	3.625· —	655·13	507·62	4.315·81	4.823·43	3.375·—	571·85	876·58
Great Britain	—·—	700·—	700·—	496·55	203·45	—·—	795·—	795·—	745·—	50·—	—·—	712·50	712·50	660·—	52·50	—·—
Finland	—·—	196·56	196·56	176·34	20·22	—·—	210·—	210·—	210·—	13 70	— 13·70	217 50	203·80	213·10	4·40	— 13·70
France	—·—	1.305·—	1.305·—	948·40	268·05	88·55	1.267·50	1.356·05	1.177·30	178·75	—·—	1.260·—	1.260·—	1.157·55	102·45	—·—
Holland	59·83	317·52	377·35	210·—	155·40	11·95	309·96	321·91	195·93	54·16	71·82	317·52	389·34	262·50	39·75	87·09
Italy	—·—	382·50	382·50	240·—	140·40	2·10	442·50	444·60	352·50	55 —	37·10	345·—	382·10	300·—	30·—	52·10
Luxembourg	—·—	—·—	—·—	—·—	—·—	—·—	—·—	—·—	—·—	—·—	—·—	45·—	45·—	45.—	—·—	—·—
Norway	50·36	313·34	363·70	208·34	65·97	89·39	331·66	421·05	277·77	57·50	85·78	292·73	378·51	276·47	25·92	76·12
Austria	425·21	2.541·21	2.966·42	2.667·—	275·29	24·13	2.451·68	2.475·81	1.785·—	426·40	264·41	2.505·71	2.770·12	1.890·—	605·23	274·89
Portugal	1·30	105·—	106·30	60·—	43·60	2·70	105·—	107·70	97·50	9·85	0·35	105·—	105·35	88·55	6·80	10·—
Roumania	29·40	130·—	159·40	140·—	24·40	— 5·—	162·50	157 50	110·—	25·20	22·30	120·—	142 30	110·—	14·60	17·20
Russia	—·—	1.568·30	1.568·30	1.289·40	279·60	—·—	1.540 77	1.540·77	735·—	805·77	—·—	1.166·76	1.166·76	525·—	641·76	— —
Sweden	21·25	390·—	411·25	341·79	69·46	—·—	390·—	390·—	390·—	—·—	—·—	367·50	367·50	367·50	—·—	—·—
Switzerland	33·50	656·15	689·65	587·70	98·55	3·40	671·20	674·60	525.—	112·17	37·43	662 50	699·93	576·65	93·40	29·88
Servia	—·—	22·50	22·50	20·95	1·55	—·—	22·50	22 50	20·25	2·25	—·—	22·50	22·50	22 50	1·25	— 1·25
Spain	—·—	—·—	—·—	—·—	—·—	—·—	187·50	187·50	187·50	—·—	—·—	202·50	202·50	202·50	—·—	—·—
Hungary	—·—	567·—	567·—	497·70	80·69	— 11·39	596·82	585·43	537·60	33·79	14 04	574·44	588·18	462·—	30·91	95·27
United States of America	—·—	2.004·66	2·004·66	1.355·11	649·55	—·—	2.109·62	2.109·62	1.763·85	345·77	—·—	2.298·78	2.298·78	2.178·96	119·82	—·—
Total	1546·75	16.112·48	17.659·23	13.428·40	3512·15	718·68	16 984·14	17.702·82	13.737·84	2894·40	1070·58	16.904·64	17.975·32	13.998·34	2394·73	1582·15

FINANCIAL RETURNS FOR THE YEARS 1906, 1907 AND 1908.

NUMBER OF MEMBERS IN AUGUST.

	1906	1909
Argentine	1	1
Australia	4	17
Austria	182	225
Belgium	66	82
Brasil	2	4
Canada	2	8
Chili	1	3
Denmark	51	199
France	172	166
Germany	351	375
Great Britain	64	108
Greece	—	1
Holland	43	43
Hungary	76	89
Italy	51	65
Japan	1	1
Luxembourg	4	10
Norway	41	50
Portugal	14	17
Roumania	21	20
Russia:	362	299
(Finland)	(30)	(33)
Servia	3	3
Spain	25	27
Sweden	53	61
Switzerland	75	83
United States of North America	241	290
Total	1906	2247

LIST OF PUBLIC BODIES,
Societies and Individuals, supporting the International Association.

Kgl. preußisches Kriegsministerium, Berlin	550	M
Verein Deutscher Ingenieure, Berlin	100	„
Verein deutscher Eisenindustrieller, Berlin	100	„
Verein zur Beförderung des Gewerbefleißes, Berlin	100	„
Verein deutscher Eisenhüttenleute, Düsseldorf	100	„
Hohenlohe-Werke, A.-G., Hohenlohehütte, O. S.	100	„
Verein deutscher Portland-Zementfabriken, Heidelberg	60	„
Deutscher Verband für die Materialprüfungen der Technik	50	„
Verband Deutscher Architekten- und Ingenieur-Vereine, Berlin	50	„
Verein deutscher Chemiker, Mannheim	20	„
Berliner Bezirks-Verein deutscher Ingenieure	20	„
Deutscher Verein für Ton-, Zement- und Kalkindustrie, E. V., Berlin	10	„

Verein der österreichischen Zementfabrikanten, Wien	500	K
Zentralverein der Bergwerksbesitzer Österreichs, Wien	100	„
Niederösterreichischer Gewerbeverein, Wien	100	„
Österreichischer Ingenieur- und Architektenverein, Wien	100	„
Prager Eisenindustrie-Gesellschaft, Wien	100	„
Verein der Montan-Eisen- und Maschinenindustriellen, Wien	100	„
Österr. Alpine Montan-Gesellschaft, Wien	50	„
Dampfkessel-Untersuchungs- und Prüfungs-Anstalt, Wien	50	„
K. k. pr. ö. Bodenkreditanstalt, Wien	50	„
K. k. Direktion für den Bau der Wasserstraßen, Wien	30	„
Golleschauer Portlandzementfabriken, Wien	10	„

Dansk Ingeniör-Forening in Kopenhagen	50	Frcs
Tekniske Forening in Kopenhagen	25	„

American Society for Testing Materials	100	Frcs

The Iron and Steel Institute, London	125	Frcs
The British Fire Prevention Committee	63	„
F. Tomlinson, Manchester	25	„

Hungarian Society for Testing Material, Budapest . . . . 50 K

Administration Centrale des chemins de fer de l'Etat russe . . . . . 125 K
Bureau des fabricants des ciments russes . . . . 100 „
Bureau des Forges . . . . 100 „
Administration du chemin de fer de Perm . . . . 50 „
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„ „ „ „ „ „ Riga Orel . . . . 50 „
„ „ „ „ „ „ Moscou-Koursk . . . . 50 „
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„ „ „ „ „ „ Nikolas . . . . 50 „
„ „ „ „ „ „ Charkow-Nikolaeft . . . . 50 „

Jernkontoret, Stockholm . . . . 100 K

Generaldirektion der Schweizerischen Bundesbahnen in Bern . . . . 50 Frcs
Verein Schweizerischer Zementfabriken in Dittingen . . . . 50 „
Verein Schweizerischer Maschinenindustrieller, Zürich . . . . 50 „

Vco.\-

BY-LAWS
OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

RESOLVED AT THE BUDAPEST CONGRESS 1901. AMENDED AT THE BRUSSELS CONGRESS 1906, AND AT THE COPENHAGEN CONGRESS 1909.

§ 1.

The Association shall be called "The International Association for Testing Materials".

§ 2.

The objects of the Association are: the development and unification of standard methods of testing; the examination of the technically important properties of materials of construction and other materials of practical value and also the perfecting of apparatus used for this purpose.

These objects will be furthered:

1. By the Congresses and other meetings of the Association.
2. By the publication of an official Journal.
3. By any other means that may appear desirable.

§ 3.

The funds necessary for carrying out the purposes mentioned in § 2 will be raised by

1. The annual subscriptions of members.
2. Profits from the official Journal.
3. Other contributions.

§ 4.

Any person can become a member upon being proposed by two members of the Association.

Official bodies and technical societies can enter direct on their sending in their application for membership.

Applications for membership must be sent in writing to the President or to a member of the Council.

Resignations of membership must also be sent in the same way.

§ 5.

It is the duty of every member to further the interests of the Society to the best of his ability.

Every member is required to pay an annual subscription of at least 8 Mks. = 8 shillings = 2 Dollars.[1])

The Council is authorized to increase the annual subscription in order to cover extraordinary expenses incurred in the interests of the Association.

§ 6.

Every member has the right to obtain the "Proceedings" of the Association, during the period for which his subscription has been paid.

§ 7.

The Association will hold a Congress, as a rule, every second year.

The arrangements for the Congresses will be discussed in General Meetings and in meetings of the different sections.

Sections will be formed for the different groups of materials as may be considered necessary.

At present there are three sections:

I. Metals.

II. Natural and artificial building stones, cements and mortars.

III. Other materials of practical value.

Any special questions relating to the subjects of the different sections will be considered at sectional meetings.

The members assisting at the sectional debates, under the presidency of a member of the Council, will appoint the committees of the different sections.

The results of the deliberations of the different sections must be communicated at a General Meeting which will pass resolutions embodying the proposals of the sections.

Reports of Commissions, proposals of the Council and other matters te be laid before the Congress, will be printed in German, French and English, and will be sent (in the language preferred)

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[1]) Subscriptions are to be paid to the duly appointed collectors in each country, the card of membership serving as a receipt. Subscriptions not paid by the 1st of July are collected through the Post-office.

to all members who have announced their intention of taking part in the Congress, within fourteen days before the meeting of the Congress, if possible.

The decisions of the Congress will be printed in all three languages and sent to all members of the Association.

§ 8.

The Council of the Association will transact all necessary business connected with the Association.

The Council will consist of the President and the duly elected members.

Every country represented in the Association by at least 20 members has the right to elect one member as member of the Council.

"For those countries where the number of members is under 20, the Council appoints a Mandatary who takes part in the Council's Meeting with voting powers."

The President will be elected by the Congress, the Council by the members belonging to the different countries.

Till such election has taken place the former members of the Council remain in office.

The names of proposed new members of the Council have to be communicated to the President before each Congress.

The two Vice-Presidents will be elected by the Council from among its own members.

The Council has the power to elect past Presidents as permanent members of Council.

The Council is entitled to transact business when it has been duly called together according to rule and when the President or one of the Vice-Presidents is present.

Retiring members of the Council are eligible for reelection.

If a member of the Council resigns during his term of office, the President shall immediately direct the election of a successor by the members belonging to the country in question.

In the event of the death or resignation of the President, the Council will appoint one of its members to carry on the presidential duties till the next Congress.

The term of office of the Council lasts from one Congress till the next.

§ 9.

The business of the Association will be attended to by a salaried General Secretary under the direction of the President.

The members of the Council will attend to the business of the Association in the country which they represent.

§ 10.

The resolutions of the Congresses on technical questions merely serve to express the opinion of the majority. They are therefore in the form of recommendations and are in no way binding.

§ 11.

The resolutions of the Congresses can only be carried if at least three fourths of the recorded votes are in favour of them. Every member of the Association present, as well as every representative of official bodies and technical societies has one vote.

The rights and duties of a member of the Association are not altered by the fact of his belonging at the same time to a national or other Association, which Association is itself a member of the International Association.

§ 12.

The technical problems to be considered by the Association will be decided upon by the Congresses and by the Council, and will be duly referred to commissions or referees appointed by the Council.

§ 13.

The Council draws up its own regulations according to the by-laws of the Association and to the needs which may from time to time present themselves.

§ 14.

In the event of the Association being dissolved, any funds belonging to it will be handed over to the "International Red Cross Association".

AGENDA OF THE XIXth COUNCIL'S MEETING,

HELD IN THE TOWN HALL AT COPENHAGEN, SEPTEMBER 5th, 6th AND 11th, 1909.

1st Day of Meeting, Sept. 5th 2. p. m.

Members present: The President, Mr. A. Foss,

Vice-presidents, Professor Dr. A. Martens, Groß-Lichterfelde,
His Excellency Professor Dr. Belelubsky, St. Petersburg.

Permanent member of Council, Dr. Franz Berger, Vienna.

Members elected, Prof. J. Benetti, Bologna,

Mr. L. Bienfait, Amsterdam,
Dr. Charles B. Dudley, Altoona,
Mr. A. Greiner, Seraing,
Prof. H. I. Hannover, Copenhagen,
Prof. B. Kirsch, Vienna,
Mr. G. C. Lloyd, London,
Mr. S. A. Lund, Christiania,
Prof. A. Mesnager, Paris,
Mr. C. Mironesco, Bucharest,
Prof. A. Rejtő, Budapest,
Mr. J. O. Roos af Hjelmsäter, Stockholm,
Prof. J. Schüle, Zurich,
The General-Secretary: Mr. E. Reitler.

Accompanying Mr. A. Greiner:

Mr. H. de Gorski, Seraing.

The President welcomed the gentlemen assembled, thanking them for appearing in such large numbers, and expressing a wish for

the good success of the Congress. He presented to the Council the King's invitation to dine with him on Monday evening.

Passing of Minutes of XVIII[th] Council's Meeting.

Minutes passed.

Nomination of honorary presidents and secretaries.

The President laid before the Council the following list of honorary presidents and honorary secretaries, which was to be submitted to Congress for ratification.

Honorary Secretaries of the full Meeting.

Colonel Brignon, Directeur des Ateliers de l'Artillerie à Puteaux
Professor P. D. C. Kley of the Technical College in Delft.
G. C. Lloyd, Secretary, Iron and Steel Institute, London.
Baurat A. Greil, Leiter der städt. Versuchsanstalt in Wien.

Honorary Presidents.

Section A (Metals).

Germany: Wirkl. Geheimer Oberbaurat Dr. *H. Zimmermann,* Berlin.

Belgium: *Léon Thiriot,* Chief Engineer, Director of the Belgian State Railways, Brussels.

Great Britain: *J. E. Stead,* F. R. S., London.

France: *H. Le Chatelier,* Inspecteur général des Mines, Membre de l'Académie des Sciences, de l'Institut de France, Paris.

Italy: *St. Fadda,* Ingénieur-Directeur des chemins de fer de l'Etat, Rome.

Holland: *J. Schroeder van der Kolk,* Govt. Engineer, the Hague.

Norway: *I. E. Gunstensen,* Director d. Technischen Lehranstalt, Trondhjem.

Austria: His Excellency Geheimrat Sektionschef Dr. *Wilhelm Exner,* Vienna.

Switzerland: *Julius Weber,* President of the Swiss Locomotive Works, Winterthur.

Hungary: *Geduly Gyula,* Ministerialrat, Director of the Hungarian State Railways, Budapest.

Russia: His Excellency *D. Tschernoff,* Professor, St. Petersburg.
United States: *W. R. Webster,* Consulting Engineer, Philadelphia.
Sweden: Chief Engineer *J. Brinell,* Stockholm.
Denmark: *G. A. Hagemann,* Director of the Technical High School, Copenhagen.

Honorary Presidents.

Section B (Stone, Cements etc.).

Germany: Geheimer Oberbaurat *W. Germelmann,* Berlin.
Belgium: *Van Volsom*, Engineer, Brussels.
Great Britain: *Edwin O. Sachs,* F. R. S., London.
France: *H. R. Feret,* Directeur du Laboratoire des P. E. C., Boulogne-sur-mer.
Italy: *Claudio Segré,* Ing., Director auprès des ch. d. f. de l'Etat, Rome.
Holland: *M. Haaymakers,* Captain of the Corps of Engineers, the Hague.
Norway: Professor *J. H. L. Vogt,* Christiania.
Austria: Sektionschef Dr. *Franz Berger,* Vienna.
Switzerland: Director *Haas,* President of the Swiss Association of Cement Manufacturers, Dittingen.
Hungary: Hofrat Professor *Désider Nagy,* Budapest.
Russia: *W. Czarnomsky,* Ingenieur, St. Petersburg.
United States: *Rich. L. Humphrey,* Consulting Engineer, Philadelphia.
Sweden: *Axel Lindhal,* Lieutenant Colonel, Stockholm.
Denmark: *H. C. V. Möller*, President of the Technical Society, Harbour Chief Constructor, Copenhagen.

Honorary Presidents.

Section C (Various Materials).

Germany: Wirkl. Geheimer Oberbaurat *Veith,* Berlin.
Belgium: *E. Camermann,* Chief of the Testing Department, Belgian State Railways, Brussels.
Great Britain: *J. T. Milton,* Delegate of Lloyd's Register of British & Foreign Shipping, London.
France: *F. Cellerier,* Directeur du Laboratoire d'Essais du Conservatoire National des Arts et Métiers, Paris.
Holland: *A. J. M. Stoffels,* Government Director of Construction, the Hague.
Norway: *E. Simonsen,* Chemical Expert, Christiania.

Austria: *Heinrich Zweig,* Chief Government Naval Architect, Vienna.

Switzerland: *Keller,* Chief Enginer Swiss Federal Railways, Bern.

Hungary: *A. Grittner,* Inspector of the Royal Hungarian State Railways, Budapest.

Russia: Prof. *A. Kroupsky,* St. Petersburg.

United States: Prof. *W. K. Hatt,* Civil Engineer, Lafayette, Ind.

Denmark: Prof. *N. G. Steenberg,* President of the Danish Society of Engineers, Copenhagen.

Honorary Secretaries.

Section A (Metals).

Germany: Professor Dr. *E. Meyer,* Techn. High School, Charlottenburg.

Belgium: *A. Galopin,* Sub-manager of the National Small Arms Factory, Liége.

Grand Britain: Dr. *W. Rosenhain,* National Physical Laboratory, Teddington.

Italy: *F. Giolitti,* Dr., Prof., Turin Polyteehnikum.

Holland: *P. Maas Geesterann,* Chief Engineer Dutch Railway Co., Amsterdam.

Norway: *Chr. Storm,* Engineer, Trondhjem.

Switzerland: Prof. Dr. *P. Weiß,* Federal Politechnikum, Zurich.

Hungary: Dr. *W. Misángyi,* Engineer, Budapest.

Russia: His Excell. *Klemm,* Governor Councillor, St. Petersburg.

Honorary Secretaries.

Section B (Cements).

Germany: Prof. *Max Möller,* Techn. High School, Brunswick.

Belgium: *Mm. Hiertz,* Chief of Blast Furnace Dep , Cockerill Works, Seraing.

Italy: *G. Revere,* Ingénieur, Professor, Milan.

Holland: *J. A. v. d. Kloes,* Professor, Techn. High School, Delft.

Norway: *J. G. Lund,* Professor, Trondhjem.

Switzerland: *R. Frey,* Director Cement and Lime Works, Luterbach.

Hungary: Dr. *B. v. Brzesztovsky,* Prof. Techn. High School, Budapest.

Russia: Prof. *P. Welikhoff,* Engineer, Moscow.

Honorary Secretaries.

Section C (Various Materials).

Germany: Prof. Dr. *Hinrichsen,* Groß-Lichterfelde.

Belgium: *H. de Gorski,* Engineer, Private Secretary to the Director of the Cockerill Works, Seraing.

Hungary: *Franz Just,* Chief Engineer, Hungarian State Railway, Győr.

Norway: *Joh. Gram,* Dr., Chemist, Norwegian State Railways, Christiania.

Russia: *A. Bormann,* Engineer, St. Petersburg.

Members of Council who open the Sections:

Section A: Prof. Dr. A. Martens, Geheimrat, Gr.-Lichterfelde.
„ B: Prof. F. Schüle, Zurich.
„ C: Prof. A. Mesnager, Paris.

Auditors of the Books:

A. Granfelt, Director, Helsingfors.
L. Bienfait, Engineer, Amsterdam.
S. A. Lund, Engineer, Christiania.

The following gentlemen are the **Chairmen in charge** of the sections:

Section A: O. F. A. Busse, Director of the Danish State Railways, Copenhagen.
„ B: T. Grut, Captain, Copenhagen.
„ C: B. Münter, Commandeur, Copenhagen.

The General Secretary stated that the number of papers sent in had considerably exceeded that anticipated at the XVIII[th] Council's Meeting. In spite of several very considerable delays in their arrival, all the reports received for the Congress had been printed in time and despatched to the members, with the exception of a report by Mr. Tagueff in St. Peterburg, which arrived so late that it could not be printed and therefore could also not be submitted to the Congress.

His Excellency Prof. Belelubsky gave notice of another delayed supplement to the report of the Reinforced Concrete Committee.

Choice of the next Place for Congress.

His Excellency Prof. Belelubsky stated that he was authorised by the Ministry for Internal Communication to announce that Russia desired the right of convening the VIIth Congress at St. Petersburg in the year 1913 or later.

Mr. Ch. Dudley presented au invitation from the American Society for Testing Materials, numbering at the present time 1160 members, to hold the VIth Congress of the International Association in 1912 in the United States of America, place and time to be settled later. As the Congress for Applied Chemistry was also to take place in the United States in 1912, and possibly a Meeting of the Iron and Steel Institute it was hoped that an agreement might be come to, as to the time of these three congresses, in order to facilitate the taking part in them all.

The President offered his best thanks both for the invitation for the VIth as also for that for the VIIth Congress.

After Mr. Dudley had, in reply to an interrogation of Mr. Martens stated that the three Congresses would take place one after the other and not simultaneously, and, further, as near as possible to the end of August or at the beginning of September in Washington or New York, the further discussion of this question was postponed to the next day's sitting.

Debate upon increasing the income of the Association.

President Foss referred to the successful publication of the Proceedings, and proposed an increase of the members subscription, in order to make it possible to continue the publication and distribution of the Proceedings free of cost in the manner begun under such favourable circumstances.

Dr. Berger proposed an appeal to the Council's members in order to obtain larger subventions from Associations and governments.

Prof. Schüle considered the increase of members' subscription not sufficiently efficacious, as it would be disagreeable to so many. He supported the proposal of Dr. Berger which should however receive further emphasis through a decision of the Congress.

Dr. Dudley referred to the example of America, where the Association with its large expenses, had by a considerable increase

of the members' subscription made itself entirely independent especially of the influence of subvention paying Associations.

Dr. Berger believed there was no need to fear such an independence of the Association.

His Excellency Prof. Belelubsky proposed dividing the papers into official and non-official, and asking an extra sum for the postage without increasing the members' subscription.

President Foss advocated the increase to 10 Frcs. M. Martens and Bienfait supported that proposal.

Prof. Mesnager advocated a supplementary payment for the Congress papers; he did not find it suitable to send these papers to Congress members and to non-Congress members.

Mr. Dudley recommended that the «Proceedings» should be sent to the members from time to time in order to keep up their interest in the Association.

Prof. Rejtő advocated an increase of subscription from 6 to 8 sh, the council reserving the right of proposing a further increase for the Congress papers.

The close of the debate and the drawing up of a resolution was postponed till the following day.

The General Secretary brought forward a letter from Mr. v. Banovits, in which he expressed his regret at being obliged to lay down his functions as Council's member on account of illness, and stated that the election had been unanimous for Prof. Rejtő.

Mr. Dillner stated in a letter that he was prevented, by urgent professional business, continuing his functions as member, and that Mr. of Roos had unanimously been elected in his place

The resignations of the two gentlemen were received with much regret.

Finally Messrs. Bienfait, Granfelt and Lund were requested to undertake the auditing of the books.

Conclusion of meeting 5 o'clock.

2nd Day. Monday, 6th Sept., 11 a. m.

President Foss in the Chair. Present as before.

The President stated that Dr. Michaelis had informed him of his inability to be present at the Congress.

Mr. Bienfait, in the name of the auditors, declared that the latter had audited the books for the years 1906 to 1908 and the current year, and had found correct the amount of cash in hand, K 3952·30 deposited in the Depositenbank in Vienna. He begged to express the opinion of the auditors that the books were kept in a manner deserving the utmost credit. (Approved.)

Continuation of the debate on the increase of the members' subscription.

The General Secretary read over the following suggestions proposed on the preceeding day:

1. In consideration of the fact that the expenses of the Association have been largely increased by the publication and gratis distribution of the «Proceedings», by means of which however the cause of Testing Materials has been considerably promoted, the Council has resolved to increase the annual subscription on the 1st January 1910 from frcs. 7·50 to frcs. 10.—.

2. The Council reserves the right of taking still further measures in this direction in the Congress year.

Prof. Benetti made the following proposition in order to improve the financial situation of the Association:

1. Division of the members into 3 categories:

a) Single members with an annual subscription of 5 marks.

b) Technical Associations (with the exception of industrial and commercial Societies), with an annual subscription of 20 marks, and an official delegate with vote.

c) Industrial and Commercial Societies with the subscription of 50 Mk., and a single delegate with vote.

2. Only abstracts of reports, and other information prepared by the authors themselves, to be translated. The publications to be distributed in the original language, the abstracts in different languages according as required.

3. Reduction of salaries and other expenses of the central office.

Remark. The single members have a right to one copy each of the publications. The non-industrial Societies to 3 copies, the industrial Societies to 5 copies.

The speaker supported his proposition in the course of a long speech by specially pointing out that the Associations, particularly the industrial Associations, enjoyed the principal advantages of the work of the Association and were in a far better financial situation than the single members.

Prof. Martens believed that these propositions would entail alterations in the Statutes and By-Laws, and regarded the suggestion as not feasible on account of the great difficulties as to the voting.

Dr. Berger was of opinion that the organisation which the Association had adopted after long deliberation was not only the simplest, but had also proved itself generally successful. He regarded the new proposal as ruin for the Association.

After a long debate, the proposal to increase the members' subscription, as given in paragraph 1, was unanimously adopted in preference to that of Professor Bennetti. The second paragraph was dropped.

With regard to Professor Bennetti's proposal, it was decided to submit the same to a future Council's meeting for further consideration.

Discussion on the choice of place and president for the next Congress.

Professor Martens advocated the acceptance of the invitation to America, and proposed Dr. Dudley as President.

Dr. Dudley expressed his thanks for the honour done him and recommended Prof. Martens as President; it being however pointed out to him that the President is chosen from the country where the Congress is held, he mentioned Professor Howe as most worthy of the office, but declared himself willing to accept the position of honour if desired.

Professor Benetti expressed anxiety as to the success of the Congress, the principles for the testing of materials in America being different from those in Europe, and the Americans preferring in this domain to act independently.

The President regarded this circumstance as only another reason for holding the congress in America.

Mr. Dudley assured the meeting that much interest was taken in America in the international unification of methods, and

if the Americans had hitherto gone their own way, the reason was to be found on the one hand in the great distance from Europe, and on the other in the fact that this proceeding seemed to be the best means for developing the science of Testing Materials in America itself.

Dr. Berger again pointed out that it was necessary to hold the Congress in the beginning of September.

Dr. Dudley expressed a hope that an arrangement with regard to this point would be agreed upon with the Iron and Steel Institute, so that the Congress could be held in the autumn. With the members of the Chemistry Congress nothing had as yet been settled upon.

It was resolved to propose to the Congress that the VIth Congress should, on the invitation of the American Society, be held in America in 1912, and that Dr. Charles B. Dudley should be elected President of the Association.

As regards the Russian invitation it was resolved to submit the following proposal to the Congress.

„The Congress has received with much gratitude and good will the invitation of the Russian Government conveyed by Professor Belelubsky, and will willingly accept the said invitation."

In conclusion the Council resolved that Prof. Schüle should officially convey the congratulations of the Council to Professor Dr. Lunge of Zurich on the occasion of his 70th birthday.

Close of meeting 12. 30. p. m.

3rd Day of Meeting, Saturday, September 11th 1909.

Beginning at 9 a. m.

Place and members present as before.

The President read out the following proposals to be submitted to the Congress.

"In consideration of the great importance of the work of the International Association for Testing Materials for the public security and in consideration of the necessity making their work

as widely known as possible and of placing the finances of the Association upon a more satisfactory basis, the Congress decides to authorize the Council to call the attention of governments, public bodies and scientific and industrial undertakings to the work of the International Association and to induce them to manifest their interest therein by giving financial support.

(Agreed to.)

The Congress decides to hold the VIth Congress at the invitation of the American Society for Testing Materials in the United States of America in Autumn 1912, and to elect Dr. Charles B. Dudley President of the International Association.

(Agreed to.)

The Congress accepts with warm thanks the invitation of the Russian Government presented by His Exc. Prof. Belelubsky to hold the VIIth Congress in St. Petersburg. (Agreed to.)

The President read the resolution passed by the Council as to the increased members subscription to 8 sh ($ 2.—) and announced that he would bring it to the knowledge of the Congress.

(Agreed to.)

He then proposed to submit to the Congress the following alterations of the By-Laws:

In § 6 the words "on paying the fixed reduced price" and the foot-note in connection with the same are to be scratched out, owing to the fact that the „Baumaterialienkunde" has ceased to appear and that the Council publish their own journal the "Proceedings". (Agreed to.)

After this the resolutions passed by Sections A, B and C were read out to be submitted to the Congress.

Metals.

Metallography.

In pursuance of the communication of Mr. Rosenhain in which is emphasised the importance of the question of slag en-

closures in metallurgical products the Congress recommends the appointment of a Commission for the purpose of studying methods for determining the enclosures, their influence upon the mechanical properties of metallurgical products and for the study of this question in the whole.

Hardness Tests.

The Congress requests that the Council shall arrange that at the next congress in conjunction with the problem of the determination of hardness by ball or cone pressure-tests, the investigation of uniform tests for the resistance of materials to mechanical wear be reported upon, and that they consider the advisability of referring the problem to a committee.

Impact Tests.

A. In order to facilitate the comparison of results of impact bending tests on notched bars the Congress recommends the use of following rules, unless prevented by special circumstances.

1. The notched bar impact test permits the determination of the specific work of rupture or resilience referred to the sq. centimeter of the notched section.

2. a) The bars cut to sufficient length have the following dimensions: $30 \times 30 \times 160$ mm. They are notched to a depht of 15 mm. The bottom of the notch bar is cylindrical of 2 mm radius.

b) For rolled materials such as plates, the bars have the same thickness as the plate, the surface of which are preserved and a width of 30 mm. They are notched to a depth of 15 mm. The notch is perpendicular to the surface of rolling and has a cylindrical bottom of a radius of 2 mm.

c) For pieces which do not permit the use of bars 30×30 mm in section the bars are 10×10. They are notched to a depth of 5 mm. The bottom of the notch is cylindrical with a radius of $^2/_3$ mm.

d) The size of the bars used is always to be recorded.

3. The bars are tested by bending and receive at their centre upon the side opposite to the notch the impact of the drop weight with a knife's edge rounded to a radius of 2 mm. They rest on knife edges spaced 120 mm apart in the case of types a) and b) and 40 in the case of type c).

4. The rupture of the bar shall be effected by a single blow by means of an apparatus which enaples the work absorbed by the rupture to be measured.

5. The temperature should be as nearly as possible between 15 and 25 degrees C. and in all cases shall be noted with the results of the tests.

B. The Congress recommends that a Committee be appointed to collate all the results which permit the establishment of connection between the properties manifested under the tests and the behaviour of the pieces in service and that this committee also study the comparison of the various apparatus.

Alternating Stresses.

The Congress takes note of the reports presented and expresses their best thanks for them.

Cast Iron.

The Congress recommends to refer the problem of methods for testing cast iron (dealt with by Committee 25) to Committee I.

Influence of increased Temperature on Mechanical Qualities of Metals.

The Congress takes note of the excellent report of Professor Rudeloff and expresses him their warmest thanks.

Electric and Magnetic Properties in Testing Metals.

The Congress recommends the nomination of a committee for studying the use of the electrical and magnetical properties of metals for testing metals.

International Specifications for Iron and Steel.

The V^th International Congress welcomes the work of the Sub Committee Ia with pleasure and approves in general the principles laid down in the Congress report $VIII_1$ and decides: Committee I and Sub Committee Ia are invited to continue their valuable labours in cooperation with the National Societies and if possible to lay before the VI^th Congress definite proposals as to the basis of International specifications for iron and steel.

Pig Iron.

For the purpose of defining more accurately the quality of Pig Iron than is possible by the present method of grading by fracture appearance, the Congress recommends that Committee I (Sub Committee Ia) be instructed to inquire in the various countries concerned as to how far specification on analysis may be usefully substituted for the present method of grading by fracture appearance and that they be authorised to take such steps as they may deem advisable to give effect to this resolution.

Nomenclature of Iron and Steel.

The Congress takes note of the report of Committee 24 upon Nomenclature of iron and steel and expresses their warmest thanks to this Committee for their work. They recommend that the committee remain in function and that they prepare for the next congress a revision of their proposals for uniform nomenclature taking account of the further progress in metallurgy and of any suggestion which may be received from the National Societies for Testing Materials. The Congress approves the list of definitions of structure constituents of steel presented by Prof. H. Le Chatelier.

Specifications for Copper.

The Congress expresses their best thanks of the work of the Committee on Copper and approves the proposal of the Committee to extend the scope of their work and include the study of specifications for copper alloys.

Standards for Wrought Iron Pipes.

The Congress takes note with thanks of the valuable report of Mr. Karsten on the specifications for wrought Iron Pipes and refers it to Committee I for examination and laying a report to the next Congress excluded the thread question.

Cement, Stones, Concrete.

Reinforced concrete.

The Congress thanks the Committee 41 for the work already done and invites them to continue upon the plan described by

Prof. Schüle, and expresses the wish that the Committee be supported financially by the competent institutions and authorities.

Testing Cements by Prisms.

The Congress thanks Committee 42 for the work already performed and recommends to continue their investigations on the same lines with due consideration of the results obtained by the Hungarian committee, to wich the Congress expresses their warmest thanks. The Congress expects that the Committee will be able to proprose to the next congress a definite method of using plastic mortars for the testing of cement.

Constancy of Volume.

The Congress decides to recommend the method of Le Chatelier as the standard accelerated test for the constancy of volume of cements [1]).

Accelerated Test of the Strength of Cements.

The numerous hot-water test-results given are in fact so contradictory, that this test appears too unreliable to admit of its being employed for rapid tests made to determine the strength of hydraulic cements.

Under these circumstances, the Congress does not recommend further pursuing the question of the applicability of the hot-water test for rapid tests of the strength of hydraulic cements.

On the other hand the experiments of Mr. Deval have once more demonstrated how valuable this test can be for information as to the constancy of volume.

Finest particles in Cement.

The Congress begs Committee 30 to continue their work on the adopted lines and to report on the results at the next Congress.

Methods recommended by the IVth Congress.

The Congress alters § 3 . c about the methods recommended at the Brussels Congress for cement to run as follows:

[1]) Adopted with the reservation of Congressists from Germany.

A conical ring 7,5 cm in diameter at the base, 8,5 cm at the top and 4 cm deep placed on a glass plate, is immediately filled with the paste, and the excess is struck off with the trowel, pressure on the paste and agitation being avoided.

Gypsum.

The Congress resolves to leave the question of specification for Gypsum to the next congress.

Puzzolana.

The Congress leaves the question of the testing of Puzzolanas to the next congress.

Standard Sand.

A Committee is appointed to investigate, whether or not an international standard sand be possible, and if not to secure information showing the comparative value of the different national standard sands[1]).

Cement in sea water.

The Congress recommends the appointment of a small committee.

a) to obtain by December 1910 any additional information or supplements to the reports presented at the Congress of Copenhagen, they may require,

b) to summarize these reports and supplements and present the summary of results in a brief form to the next congress,

c) to collect information on the effect of seawater on Portland cement sea structures of more than 25 years standing,

d) to arrange for certain tests (proposed by Mr. Leduc) on the effect of sea water on specially prepared cement.

Weather Resistance of Building Stones.

A committee is to be formed for the purpose of investigating the influence of the mortar composition and the quality of the building stone on the weather resistance of the masonry.

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[1]) Committee 42 is entrusted with studying this matter.

Sundries.

Wood.

The Congress recommends to appoint a committee on wood testing which has to communicate with the national societies existing in different countries. This committee has especially to examine the desirability of making wood tests on larger pieces containing defects or variations in structural form instead of limiting the tests to small perfect pieces.

Paints.

(Proposal by Mr. Decamps.)

The question of galvanisation not yet having been studied in the reports, the Congress desires to have researches made as to galvanisation and even to tin coating.

(Proposal by Mr. Münter.)

The Congress considers it highly desirable that special attention be given to the question of keeping clean the bottom of iron and steel ships, and charges the Council to have this most important question investigated.

Dr. Berger proposed to bestow upon Mr. Foss — now resigning his functions as President — the highest honour in the power of the Association, namely to elect him Permanent Member of the Council. In view of the great services rendered by Mr. Foss, as regards the complete success of the Congress, the speaker did not think it necessary to add anything further in support of this motion. (Agreed to with loud applause.)

Mr. Foss thanked for this unlooked-for honour and assured the Meeting that he would always have the interests of the Association at heart.

Dr. Dudley begged Prof. Martens, as 1st Vice-President of the Association, to convene and preside at the next Council's Meeting in his place, he being unable to come to Europe.

Prof. Martens agreed and proposed to convene the Meeting in the beginning of February. (Agreed to.)

After this, Meeting closed 10 a. m.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

V2

ON UNIFORM METHODS OF TESTING CAST IRON.

Official report presented by Dr. **R. Moldenke**, New York, chairman of Committee 25.

The Commission to establish uniform methods of testing cast iron and finished castings, begs to report that since the Brussels Congress considerable attention has been given to the subject of testing cast iron in various countries, and that as the nature of this material becomes better known, there is greater likelihood of a basis of agreement upon the methods of testing to be used, being arrived at eventually.

Elaborate tests have been made in Germany, which in the main agree with those carried out some years ago in the United States, and as a consequence, the three sizes of test bars specified, have been replaced by a single one. This is very important, as it shows an agreement with the American tendency to treat Cast Iron from an entirely different standpoint than steel, or other metals.

It is a well known fact that no material that we know of shows such a lack of homogeneity, or such a range of varieties from widely differing extremes in physical characteristics, as Cast Iron. Consequently a very painstaking and elaborate series of investigations of a National character helps to bring this condition of affairs home very closely to those who test and use iron castings. The published results of one Nation do not seem to carry the weight, they might be expected to have, in other countries. Every

Society or national body of engineers appears to have to dig this information out for itself, and perhaps after all this may be the best in the end.

It is with pleasure therefore that we can report, that in view of the evident impossibility of obtaining actual strengths existing in the several parts of a casting, by means of tests bars either loose or attached, the results of the most recent investigations of Germany and the United States confirm the desirability of judging castings by the quality of the metal and its suitability for the purpose. This is shown by a standard test bar, cast under the most perfect conditions possible, so that possible influences of manipulation may be excluded, and the metal used for the work is given full opportunity to show its intrinsic value. Naturally where it is possible to test the castings themselves, this is resorted to, as witness the specifications for American Car Wheels. Again, even with perfect metal, as shown by a standard test bar, improper shop conditions may spoil the work. Yet on the whole, experience, as based on thorough investigation, has shown the value of knowing exactly what the metal is that goes into the castings, rather than attempting to attach coupons or place test bar patterns of various kinds into the moulds themselves.

Perhaps the nearest approach to the latter has been obtained by the use of hollow prisms or cylinders with the same metal, and the planing out of test strips from the walls. You will have a separate repport before the congress on this very point. In the United States cylinders from which test bars were cut have been used for a long time, and are still employed in the case of munitions of war. As the cylinders have the same thickness as the projectiles, it practically becomes the taking of a piece of the casting to see how strong it is.

The German and American test bar is of practically the same diameter, and is cast under nearly the same conditions, differing only in the manner of pouring, and the fact that the German bar is twice as long. Denmark still makes use of the very long bar, loaded gradually at the centre until a maximum called for has been reached. This method was formerly much used in the United States, but found too elaborate for commercial conditions. Italy makes use of a very short bar, heavily loaded. It is interesting to note that the one foot bar of the United States is

half way between the Italian and the German test pieces. Italy further specifies a drop test on its bar, which is of interest. Denmark requires a hammer test for softness and absence of brittleness. Germany leaves out a tensile test. America makes it optional, and Italy includes it in the specifications.

Regarding the testing of castings, it may be said that cast iron pipe takes a prominent place, a number of countries having specifications for this important branch of the casting industry. The international character of the business is bringing much thought to bear on simplifying the several specifications, so that greater uniformity may result between the several countries that ship pipe abroad.

Perhaps, however, the easiest point for agreement between the countries specifying for cast iron products, might be found in the basis of the whole industry, namely in Foundry Pig Iron. The American members are presenting to this Congress the specifications newly adopted by that country, after long study and discussion, from which there will be seen that every possibility of chance has been eliminated, and a carefully divided range for every element with its variation to be allowed, is given. Perhaps a study of these specifications by the various countries may lead to suggestions and modifications which will result in an International set of Specifications for Foundry Pig Iron which will facilitate the purchase and sale of foundry pig iron the world over.

The Committee therefore reports progress, considering the complexity of the subject, and the comparative youth of the art of testing cast iron.

Sub-Committee Ia.

International Specifications for Iron and Steel.

Provisorily.

CAST IRON.

Comparative Summary of Specifications for Germany and United States of America based on the following data:

1. Specification for Cast Iron of the "Deutscher Verband für die Materialprüfungen der Technik". Adopted Sept. 1908. (Excepted Cast Iron Pipes No. 40.)
2. Standard specifications for Cast Iron Pipe and Special Castings of the "American Society for Testing Materials". Adopted 1905.
3. Standard specifications for Foundry Pig Iron of the "American Society for Testing Materials" revised 1909.
4. Standard specifications for Locomotive Cylinders of the "American Society for Testing Materials". Adopted 1905.
5. Standard specifications for Gray Iron Castings of the "American Society for Testing Materials". Adopted Sept. 1st 1905.

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	Engine
	Ordinary
No. of specimen bars	
Size of specimen bars.	Length: 2 Dia.:
Load.	1090 lbs. (495 kg)
Bending strength.	$17^3/_4 \frac{\text{sq. in.}}{\text{tons.}}$ (28 kg/mm²
Required deflection.	At least $^9/_{32}$" (7 mm).
Distance of supports.	
Speed of testing.	
b) Tensile Test.	
c) Hydrostatic Test Height of pressure	
Duration of hydrostatic test.	
Hammer test.	
15. Permissible Variations. Thickness.	

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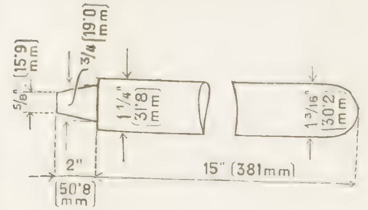
Specifications for Cast Iron.

	Germany				United States of America			
	Engine Castings: Ordinary	Engine Castings: Higher Tensile Strength	Castings for Buildings and Pillars	Pipe Castings (Socket pipes for Gas and Water piping. Flanged pipes for Gas, Water and Steam piping. Appertaining Specials.)	Cast Iron Pipe and Special Castings	Foundry Pig Iron	Locomotive Cylinders	Gray Iron Castings
11. Checking.			Adherence to specified thickness is proved by boring at suitable spots in each instance of 2 opposite points, in the case of pillars cast horizontally, in the direction corresponding to the possible sag of the core.		The sockets and spigots will be tested by circular gauges.			
12. Chemical Analysis.						Recommended.		
13. Chemical Composition.						Silicon: from 1·00 to 3·50 %. Sulphur: from 0·04 to 0·1 % Total Carbon: 3·00 to 3·80 % Manganese 0·20 to 1·50 % Phosphorus 0·20 to 1·50 % (gravimetric).	Silicon from 1·25 to 1·75 %. Phosphorus: not over 0·9 %. Sulphur: not over 0·10 %.	Where section less than 1/2" (13 mm) thick, not over 0·08 % Sulphur. Where no section is less than 2" (51 mm) thick 0·12 % Sulphur. Otherwise (medium castings) 0·10 % Sulphur.
14. Physical Tests. a) Bending test. Manner of testing.	In the event of the specimen bars having to be cast for some reason or other in divided molds, the specimen bar is to be put upon the testing machine in such a way that the pressure is effected at right angles to the plane of the seam. The specimen bar shall be subjected to the test in an unfinished condition, i. e. with casting skin. The bending strength and the deflection are determined by gradually increased loads centrally applied to the specimen bar. Defective specimen bars are not considered in such determination. The average of the results obtained by faultless specimen bars represents the authoritative figure.							Load applied at the middle, and the deflection at rupture noted.
Manufacture of specimen bar.	Length of casting $25^{19}/_{32}$" (650 mm). In case the specimen bars are cast on the casting, special arrangements have to be made. The specimen bars are to be made from the same heat or run which was used for manufacturing the castings, in dry and, as far as possible, undivided molds, at rising casting (bei steigendem Guß), and at mean casting temperature of the cast iron. Test bar shall not be removed from the mold until cold.						Cast on end in dry sand.	Each set of 2 bars is to go into a single mold. The pattern of the bars is shown in fig. The pattern shall not be rapped before with-drawing. The flask is to be rammed up with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve, with a mixture of 1 : 12 bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried and not cast until it is cold. The test bar shall not be removed from the mold until cold enaugh to be handled.  The bars shall not be rumbled or otherwise treated, being simply brushed off before testing.

	Germany				United States of America			
	Engine Castings		Castings for Buildings and Pillars	Pipe Castings (Socket pipes for Gas and Water piping. Flanged pipes for Gas, Water and Steam piping. Appertaining Specials.)	Cast Iron Pipe and Special Castings	Foundry Pig Iron	Locomotive Cylinders	Gray Iron Castings
	Ordinary	Higher Tensile Strength						
No. of specimen bars	3		3	3	1—3 from each heat or run.		1 for each cylinder,	4 from each heat. Where heat exceeds 20t., 2 extra bars cast for each 20t. or fraction thereof above this amount.
Size of specimen bars.	Length: $23^{5}/_{8}$" (600 mm) Dia.: $1^{3}/_{16}$" (30 mm)		Length: $23^{5}/_{8}$" (600 mm) Dia.: $1^{3}/_{16}$" (30 mm)	Length: $23^{5}/_{8}$" (600 mm) Dia.: $1^{3}/_{16}$" (30 mm)	Length: 26" (660 mm) Width: 2" (51 mm) Thickness: 1" (25 mm)		Length: 14" (355 mm) Dia: $1^{1}/_{4}$ (32 mm)	Length: 15", (381 mm) Dia: $1^{1}/_{4}$" (32 mm)
Load.	1090 lbs. (495 kg)	1320 lbs. (600 kg)	1000 lbs. (455 kg)	—	1900 lbs. (860 kg) for 12" (305 mm) pipes or less. 2000 lbs. (910 kg) for pipes over 12" (305 mm).		At least 3000 lbs. (1360 kg]	2500 lbs. (1140 kg) to 3300 lbs. (1500 kg).
Bending strength.	$17^{3}/_{4}$ $\frac{\text{sq. in.}}{\text{tons.}}$ (28 kg/mm²)	$21^{3}/_{5}$ t/sq. in. (34 kg/mm²)	$16^{1}/_{2}$ t/sq. in. (26 kg/mm²)	$16^{1}/_{2}$ t/sq. in. (26 kg/mm²) Only for gas and water piping.				
Required deflection.	At least $^{9}/_{32}$" (7 mm)	At least $^{13}/_{32}$" (10 mm)	At least $^{1}/_{4}$" (6 mm)	At least $^{1}/_{4}$" (6 mm)	Not less than 0.30" ($7^{1}/_{2}$ mm) for 12" (305 mm) pipes or less. Not less than 0.32" (8 mm) for pipes over 12" (305 mm).		Not less than 0·10" ($2^{1}/_{2}$ mm)	Not less than 0·10 ($2^{1}/_{2}$ mm).
Distance of supports.					24" (610 mm)		12" (305 mm)	12" (305 mm).
Speed of testing.								20—40 seconds for a deflection of 0·10" ($2^{1}/_{2}$ mm)
b) Tensile Test.								Where specified.
c) Hydrostatic Test Height of pressure				Working pressure + $152^{1}/_{4}$ lbs./sq. in. (10 atm.). German standard pipes have to be tested up to a hydraulic pressure of $284^{1}/_{2}$ lbs./sq. in. (20 atm.).	150 up to 300 lbs/sq. in ($10^{1}/_{2}$ up to 21 atm./cm²).			
Duration of hydrostatic test.				$^{1}/_{2}$ up to 1 minute.				
Hammer test.				During the hydrostatic test with a wrought iron hammer with rounded face, weighing 2·3 lbs. (1 kg) and of usual length of shaft, with moderate power.	Under pressure and if required by engineer.			
15. Permissible Variations. Thickness.			Difference in the thickness of a section shall not exceed, for pillars up to $15^{3}/_{4}$" (400 mm) average dia. and 13' (4 m) long, $^{3}/_{16}$" (5 mm). For pillars of a greater length, the permissible difference may be increased by $^{1}/_{50}$" ($^{1}/_{2}$ mm) for every additional $3^{15}/_{16}$" (100 mm) in dia. and 3' 3" (1 m) in length.	At the expense of the internal dia.: for straight pipes of $3\ ^{1}/_{32}$"- $3\ ^{5}/_{16}$" (25-100 mm) bore ±15% $3\ ^{5}/_{16}$"- $8^{27}/_{32}$" (100-225 „) „ ±12% $9^{27}/_{32}$"-$18^{11}/_{16}$" (250-475 „) „ ±11% $19^{11}/_{16}$ (500 mm) and overbore ±10% For standard straight specials, the double variation is permissible, same as for pipes. For piping, the material of which is subject to destructive influences the thickness is to be increased correspondingly.	Pipes ± 0·08" (2 mm) pipes less than 1" (25 mm) ± 0·10" ($2^{1}/_{2}$ mm) pipes 1" (25 mm) and more, except that for spaces not exceeding 8" (203 mm) in length in any direction, variations from the standard thickness of 0·02" ($^{1}/_{2}$ mm) in excess of above allowance. Special Castings of standard patterns are permitted to have a variation of 50% greater than allowed for straight pipe.			

tes of America

Foundry Pig Iron	Locomotive Cylinders	Gray Iron Castings
	1 for each cylinder,	4 from each heat. Where heat exceeds 20t., 2 extra bars cast for each 20t. or fraction thereof above this amount.
	Length: 14″ (355 mm) Dia: $1^1/_4$ (32 mm)	Length: 15″ (381 mm) Dia: $1^1/_4$″ (32 mm)
	At least 3000 lbs. (1360 kg]	2500 lbs. (1140 kg) to 3300 lbs. (1500 kg).
	Not less than 0·10″ ($2^1/_2$ mm)	Not less than 0·10 ($2^1/_2$ mm).
	12″ (305 mm)	12″ (305 mm).
		20—40 seconds for a deflection of 0·10″ ($2^1/_2$ mm)
		Where specified.

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6. n rust, and approved ınd out with coaltar d to make a smooth r with any tendency 149° C.) immediately nperature at the time heated shall be so an even temperature. re minutes. 149° C.) (or less if s temperature during p the mixture at the contents and refilled . After being coated Any pipe or special raped and cleaned.	
7. l casting. When cast painted in white.	
8. al-tar pitch varnish.	
9. t ends on pipes 12' half-round wrought-f the pipe.	
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1. Process of Manufacture.	
2. Manufacturing	l positic specified end dow g color to preve
3. Properties of Material.	Cast rilling a with in, etc.
4. Finish.	In aconform specifiinner a dimen diamet shall e dia-, a neat, ds. a imensic rmable l true a s. s of eve
5. Machining.	

	Germany				United States of America			
	Engine Castings		Castings for Buildings and Pillars	Pipe Castings (Socket pipes for Gas and Water piping. Flanged pipes for Gas, Water and Steam piping. Appertaining Specials.)	Cast Iron Pipe and Special Castings	Foundry Pig Iron	Locomotive Cylinders	Gray Iron Castings
	Ordinary	Higher Tensile Strength						
6. Coating (with coal tar).				Pipes and specials shall be varnished immediately after the hydrostatic test. Each casting shall be heated to a temperature of 302° F. (150° C.) before being dipped. Varnish shall not contain any substances non-dissolvable in water, and must be free from all constituents which might give the water any sort of taste. After varnishing, the coating must be dry, must adhere well to pipe and shall not scale off or stick.	No casting shall be coated unless entirely clean and free from rust, and approved by engineer before being dipped. Every pipe and special casting shall be coated inside and out with coaltar pitch varnish. To this material sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, and not brittle nor with any tendency to scale off. Each casting shall be heated to a temperature of 300° F. (149° C.) immediately before it is dipped, and shall possess not less than this temperature at the time it is put in the vat. The ovens in which the pipes are heated shall be so arranged that all portions of the pipe shall be heated to an even temperature. Each casting shall remain in the bath at least five minutes. The varnish shall be heated to a temperature of 300° F. (149° C.) (or less if the engineer shall so order), and shall be maintained at this temperature during the time the casting is immersed. Fresh pitch and oil shall be added when necessary to keep the mixture at the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch when deemed necessary by the engineer. After being coated the pipes shall be carefuly drained of the surplus varnish. Any pipe or special casting that is to be recoated shall first be thoroughly scraped and cleaned.			
7. Marking.				The internal dia. and the manufacturer's mark shall be cast on the outside of the pipes and specials.	Initials of maker's name to be cast on every pipe and special casting. When cast to order, special regulations. Weight and class shall be painted in white.		Each cylinder shall have cast on each side of saddle manufacturer's mark, serial no., date made and mark showing order no.	
8. Weighing.				Standard weight = standard dimensions × 7·25 specifid weight. × { 1·15 for standard specials × { 1·20 „ „ elbows. Weighing for payment shall be done after application of the tar coating.	Weighing for payment is done after application of the coal-tar pitch varnish.			
9. Length.					At least 12′ (3·65 m) exclusive of socket. Defective spigot ends on pipes 12′ (305 mm) or more in dia. may be cut off in a lathe and a half-round wrought-iron band shrunk into a groove cut in the end of the pipe.			
10. Standards.				Standard table of "Verein Deutscher Gas- und Wasserfachmänner" and the "Verein Deutscher Ingenieure" unless otherwise specified. — External dimensions of all pipes, as well as internal dimensions of sockets are unalterable.	According to Standards of "American Society for Testing Materials".			

	Germany				United States of America			
	Engine Castings		Castings for Buildings and Pillars	Pipe Castings (Socket pipes for Gas and Water piping. Flanged pipes for Gas, Water and Steam piping. Appertaining Specia's.)	Cast Iron Pipe and Special Castings	Foundry Pig Iron	Locomotive Cylinders	Gray Iron Castings
	Ordinary	Higher Tensile Strength						
1. Process of Manufacture.					Remelted Cupola or air furnace.			Cupola process unless furnace iron is specified.
2. Manufacturing			Slowly, cool off according to mold. — If pillars to be cast upright, it is to be specially stated.	Straight pipes of standard length shall be cast upright in well-dried molds. Small sizes up to $1^{9}/_{16}''$ (40 mm) may be cast oblique also.	The straight pipes shall be cast in dry sand molds in a vertical position. Pipes 16" (408 mm) or less shall be cast with the hub end up or down, as specified in the proposal. Pipes 18" (458 mm) or more shall be cast with the hub end down. The pipes shall not be stripped or taken from the pit while showing color of heat, but shall be left in the flasks for a sufficient length of time to prevent unequal contraction by subsequent exposure.		Cast in a dry sand mold.	
3. Properties of Material.	Cast iron machined with file and chisel.		Unless otherwise specified, gray, tough and soft cast iron machined with file and chisel.	Gray cast-iron, close grained, so soft that it can be machined with file and chisel.	Metal strong, tough and of even grain, and soft enough to admit of drilling and sutting. The metal shall be made without admixture of cinder iron, etc.		Good, close grained gray iron cast.	
4. Finish.	In accordance with specified shape and dimensions. Castings shall be smooth and neat, free from holes and cracks.		Neat and free from defects. Cross section to have specified area.	Pipes to be straight, with their inner and outer diameters concentric. Pipes and specials free from defects, smooth on side surfaces, without cracks, etc. Surface of casting shall be cleaned on inside and outside from all mold sand and roughness.	a) Pipes. The pipes shall be made with hub and spigot joints, accurately conform to specified dimensions, straight and true circles in section, with their inner and outer surfaces concentric, and of the specified dimensions in outside diameter. For pipes from 4" to 24" (102—610 mm) inclusive are 2 standards of outside dia-, and for pipes from 30" to 60" (762—1523 mm) inclusive 4 standards. For pipes: 4" to 12" (102— 305 mm) incl. 1 class of spec. castings. 14" to 24" (356— 610 mm) incl. 2 " " " 30" to 60" (762—1523 mm) incl. 4 " " " b) Special Castings. All special castings shall be made in accordance with the cuts and dimensions as specified, and must be delivered in all respects sound and conformable to specifications. The flanges on all manhole castings and manhole covers shall be faced true and smooth, and drilled to receive bolts of specified sizes. Manufacturer to deliver all bolts for bolting on manhole covers. c) Pipes and Special Castings. Sound smooth, free from scales, lumps, blisters, sand holes and defects of every nature which unfit them for intended use. All pipes and special castings shall be thoroughly cleaned.		Castings shall be smooth, well cleaned, free from blow holes, shrinkage, cracks or other defects, and must finish to blueprint size.	True to pattern, free from cracks, flaws and excessive shrinkage. In other respects, conform to whatever points specially agreed upon.
5. Machining.				Both ends to be at right angles to axle. Flanged pipes shall be supplied only with joint faces, and, unless otherwise specified, with bored flange holes also. If the latter are not to be bored, this is to be specially stated when ordering. The requirement, however, is that no bolt holes are to be found in the vertical plane through the axle of pipe. This is assuming that the main and branches are laid horizontally.				

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	Foundry Pig Iron	Locomotive Cylinders	Gray Iron Castings
			Cupola process unless furnace iron is specified.
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nd		Good, close grained gray iron cast.	
to nd er, nd		Castings shall be smooth, well cleaned, free from blow holes, shrinkage, cracks or other defects, and must finish to blue-print size.	True to pattern, free from cracks, flaws and excessive shrinkage. In other respects, conform to whatever points specially agreed upon.
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and 610 mm) dia. 5 and 1067 mm) dia. 25 mm) dia. ess 08 and 610 mm) dia. 15 and 1067 mm) dia. 72 and 1525 mm) dia. d ends.	
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percentages for the or shall not exceed lard weights of the re than $2^0/_0$.	
pes. ages for the several	
C	Silicon $\pm$ Sulphur $\pm$ n ation upw Total Carb variation ward Manganese Phospho $\pm$ 15^0 of the spe percent
16	
he weight of which pipes 16" (406 mm) in dia. shall be less than or less in dia. and pipe may be $12^0/_0$	
ive pipe or casting d point of delivery, and to be cracked.	

	Germany				United States of America			
	Engine Castings		Castings for Buildings and Pillars	Pipe Castings (Socket pipes for Gas and Water piping. Flanged pipes for Gas, Water and Steam piping. Appertaining Specials.)	Cast Iron Pipe and Special Castings	Foundry Pig Iron	Locomotive Cylinders	Gray Iron Castings
	Ordinary	Higher Tensile Strength						
Diameter.				In the event of strengthening of the socket being necessitated by strengthening shaft it is to be done at the expense of the external shape. The casts of the pattern so arising are to be borne by the purchaser.	Pipes*) ± 0·06" ($1^1/_2$ mm) pipes of 16" (406 mm) dia. or less ± 0·08" (2 mm) „ „ 18", 20" and 24" (457, 508 and 610 mm) dia. ± 0·10" ($2^1/_2$ mm) „ „ 30"—36" and 42" (762—915 and 1067 mm) dia. ± 0·12" (3 mm) „ „ 48" (1220 mm) dia. ± 0·15" ($3^3/_4$ mm) „ „ 55" and 60" (1397 and 1525 mm) dia. Special Castings*) ± 0·12" (3 mm) for castings 16" (406 mm) dia. or less ± 0·15" ($3^3/_4$ mm) „ „ 18", 20" and 24" (457, 508 and 610 mm) dia. ± 0·20" (5 mm) „ „ 30"—36" and 42" (762—915 and 1067 mm) dia. ± 0·24" (6 mm) „ „ 48", 54" and 60" (1220, 1372 and 1525 mm) dia. *) Variation in dia. of sockets and external dia. of bead ends.			
Length.				± 25/32" (20 mm) in specified length. Shorter pipes up to 5% of total delivery. Minimum length up to 3' 3" (1 m) less than standard length.				
Weight.				For straight pipes ± 5% For specials ± 10% For double branch pipes and intricate specials ± 15%. Excepted from above are branch pieces of more than $15^3/_4$" (400 mm) dia., which have greater thicknesses and, in certain circumstances, are strengthened by means of ribs.	Pipes — 5% for pipes 16" (406 mm) or less dia. — 4% for pipes over 16" (406 mm) dia. No excess above standard weight of more than the given percentages for the several sizes shall be paid for. The total weight to be paid for shall not exceed for each size and class of pipe received the sum of the standard weights of the same no. of pieces of the given size and class by more than 2%. Special Castings — 10% for pipes 12" (305 mm) and less dia. — 8% for pipes over 12" (305 mm) dia. — 12% for curves, **y** pieces and breeches pipes. No excess above standard weight of more than above percentages for the several sizes will be paid for.			
Chemical Composition.						Silicon ± 25% Sulphur ± no variation upwards Total Carbon no variation downwards Manganese ± 20% Phosphorus ± 15% of the specified percentage		
16. Rejection.				Castings with defects prejudicially affecting the tensile strength of the pipe are not to be supplied. Smaller deficiencies which are unavoidable through the nature of the process of casting and which do not in any way affect the casting in question from being put to use, are ot sufficient cause for rejection.	No plugging or filling will be allowed. No pipe will be received which is defective in joint room, the weight of which shall be less than standard weight by more than 5% for pipes 16" (406 mm) and less in dia. and 4% for pipes more than 16" in dia. No special casting shall be accepted the weight of which shall be less than standard weight by more than 10% for pipes 12" (305 mm) or less in dia. and 8% for larger sizes except that curves, **y** pieces and breeches pipe may be 12% below standard weight. Until final completion and adjustment of contract any defective pipe or casting shall be liable to rejection. However, when accepted at agreed point of delivery, the contractor shall not be liable for pipes and castings found to be cracked.			1 bar of every 2 of each set made must fulfil requirements to permit acceptance of castings represented.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

Vth CONGRESS, COPENHAGEN 1909.

XI4

CEMENT IN SEA-WATER.*)

By **A. Poulsen,** Chief-Engineer of the Danish State Hydraulic works.

(Translation from the French Original.)

Among the documents dealing with the work of the Congress, a pamphlet has been handed in entitled "Cement in Sea-water", giving information upon a series of tests which we commenced about ten years ago with a view to ascertain the principal causes which occasionally led to the deterioration of concrete work erected in the sea.

The pamphlet has been presented to you by the Scandinavian Association of Portland-Cement Manufacturers and you will find therein tabular statements and diagrams showing the results so far obtained. The limited time at my disposal does not allow me to enter into many details and I have given an abstract of the main points in this paper, a copy of which I have sent to the office of the Congreß for reproduction in our review.

The cost of the tests in question are borne by the Association of Portland-Cement Manufacturers, and the tests are being carried out in conjunction with the Norwegian and Danish Hydraulic Works authorities and staff, whose assistance has proved of great importance and value. The programme was drawn up at the time by a Committee, the members of which are Mrs. Budi, Lund (since deceased), Morris-Haslinger, Wallin, engineers who were joined

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*) Abstract of the pamphlet "Cement in Sea-Water". Report on the trials commenced in 1896 on the recommendation of the Society of Scandinavian Portland Cement Manufacturers by A. Poulsen, Copenhagen. E. & F. N. Spor, London. 3 sh.

later by Mr. Kjellström-with myself as Chairman, and entrusted with the supervision of the work as mapped out in the programme.

I shall deal here with the pamphlet above alluded to, by taking seriatim the various points mentioned in chapter 9 and enlarging upon them, as follows:

a) "The tests have been so carried out that the preliminary and the concluding operations only took place in the laboratory, a fact which enhances their practical value."

The tests in question may be said to be two-fold, in that they apply to cubes of mortar, about 3500 in number and to concrete blocks, which number over 100, $^2/_3$ m^3 (23·5 cubic feet) in volume. The blocks were made on the sea-coast off which they were to be deposited i. e. at Thyboron, at the entrance of the Limfjord into the North Sea, near the town of Lemvig. The cubes of mortar have the usual surface of 50 cm^2 (7·75 square inches) to enable them to be broken in the machine in the Laboratory; they were made in the Laboratory. The Committee acknowledge with thanks the assistance they received in this matter from the State Laboratory, Copenhagen.

From the Laboratory, the test specimens were sent, for exposure to the action of sea-water and climatic conditions, to the Vardo harbour at the extreme North-Eastern point of Norway; to Esbjerg harbour at the extreme South-Western point of Denmark and to Degerhamn harbour, on Oland island, near the South-Eastern point of Sweden, in the Baltic sea. At Degerhamn care was taken that the test specimens should not be exposed to frost, by placing them sufficiently low under water level; the sea-water at that point has but a low percentage of salt ($^1/_2$%).

At Vardo and Esbjerg, a series of specimens was similarly placed below the lowest sea level. A second series was placed at the average tide level, thus being exposed twice every day to climatic effects, especially to frost and the summer heat, which alternate with the sea-water action; the water at these points contains $3^1/_2$% of salt. The specimens are thus caused to thaw twice a day during the winter months.

The tides at Vardo have a height of 4 m (13 feet) and at Esbjerg a height of 1·5 m (5 feet). The average temperature at both harbours and these may be considered as ice-free, is $7^1/_2{}^0$ C.

(45° Fahr.), at Esbjerg and about 0° C. (32° Fahr.) at Vardo; these are the temperatures both of the water and of the atmosphere.

From what we have already said, it will be seen that specimens of mortar were deposited for test in five different spots, each series containing about 700 cubes.

Map of the Scandinavian Countries.

Cement works.

Danish near Aalborg: 1 Aalborg, 2 Denmark, 3 Norden, 4 Norresundby. — Near Mariager: 5 Cimbria, 6 Dania, 7 Kongsdaal.

Swedish: 8 Hellekis, 9 Degerhamn, 10 Visby. — Near Malmö: 11 Lomma-Limhamn, 12 Klagshamn.

Norwegian: 13 Christiania.

Long before our tests were commenced, it had been noticed that concrete work had to a large extent been deteriorated at Esbjerg and Vardo. The sets of specimens placed at both these spots were exposed to actions so pronounced and so different as

regards their likely effect, that it was hoped they would yield most precise results. With reference to Degerhamn, where the climate is equal to that of Esbjerg, a very slight effect only was anticipated, the specimens being at a good depth in sea-water having but a low percentage of salt.

Concrete tests of a similar nature have also been made at a place where the use of concrete had given unfavourable results. The concrete blocks are there placed in a groin which forms part of the dyke on the Western coast of Jutland, pier 59. Those Congress members who take part in the final excursion at Lemvig-Thyboron will have an opportunity of seeing these blocks. The average temperature of the water and the atmosphere is exactly the same as that of Esbjerg, about $7^1/_2{}^0$ C. (45^0 F.). The tides, however, are less pronounced, being 0·5 m (19 inches only).

b) "The cases built to take the test specimens have given complete satisfaction: their object was to protect the specimens against becoming damaged by shock, while allowing all physical actions to have full play."

The results aimed at might easily have been compromised by the means taken to carry out the tests; fortunately, the success of the device was complete. Each case contained 77 cubes, and we were able to lower the specimens and to raise them out of the water at the expiration of the time appointed, i. e. at the expiration of 3 and 6 months, 1, 2, 4, 6 and 10 years, without the loss of a single cube, although some were cracked and others had lost their shape completely.

c) "The marking of the test specimens by coloured glass in the shape of beads, or fragments of glass, to indicate composition and class of cement, has been entirely successful."

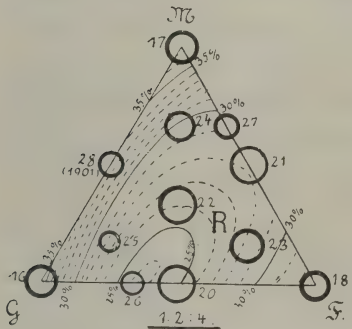
We followed this method of marking by glass beads not only for the blocks, but also for the cubes of mortar. Some specimens could not have been recognised had any other method of marking been used, whereas their origin was most accurately traced by means of the beads.

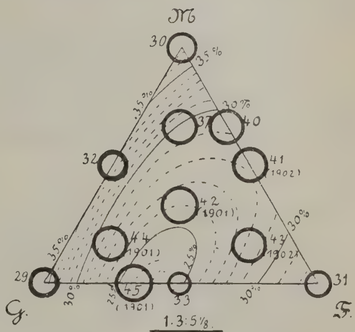
For the mortar specimens, a class of Portland-cement was selected from each of the three Scandinavian countries: 1. Aalborg (Denmark), 2. Christiania (Norway), 3. Lomma-Limhamn (Sweden). For comparison, a British Portland-Cement, "Nine Elms", was

also taken, and also a French hydraulic lime from "Le Teil". Test pieces were made using each of these classes of cement in the following proportions: 1 c : 3 s, 1 : 2, 1 : 1 and 1 : 0 (pure cement), four cubes of each proportions, using "normal sand" of Bornholm. A series was also made, using sand from the Thyboron sand-hills and Aalborg cement.

For the concrete blocks, the five above classes of cement were also selected, together with others, the manufacturers of which

Tests of concrete containing sands of varying fineness, at dyke no. 59, Thyboron.





In the two adjoining diagrams, the curves indicate the porosity of the sand mixtures as per annex 6*); the moulded blocks are designed under the numbers of the table annex 10*). One of the diagrams applies to the blocks with the 1:2:4 mixture, the other, to those with the $1:3:5^1/_8$ mixture.

The state of the blocks is shown by a circle the radius of which is equal to the figure for quality given in annex 10.

Most of the blocks were made in 1896—1897. The year is added between ( ) for those manufactured later.

agreed to take part in the competition. These were: 6. Hellekis, 7. Dania, 8. Cimbria, 9. Danmark, 10. Hemmoor, 11. Norden and 12. Aalborg quick-setting.

We also carried out a few trials with additions to the Portland-cement and with other mortars including: 1. trass, 2. infusorial earth (Mo-Ler), 3. a silicate with an addition of "Lomma", 4. slag cement, 5. a special "Dania" cement, 6. a "sand cement", 7. Kinniple-

*) Refers to the Original Report.

concrete, 8. hollow "Monier" blocks, 9. santorin[1]) and cement, 10. santorin and lime, 11. pouzzolana and cement, and 12. pouzzolana and lime.

Besides these blocks formed of different kinds of cement, we made blocks 2×12 in the proportions 1 : 3 and 1 : 2, using one and the same cement ("Aalborg") and sands of three different degrees of fineness mixed together.

These blocks were all manufactured, using fine sand-hill sand and shingle of the Thyboron sea-shore, the mortars having the proportions 1 : 3, 1 : 2 and 1 : 1, also in some cases 1 : 2·5, the proportion between the shingle and the mortar corresponding for all these mortars to that of the mixture 1 : 2 with 4 of shingle.

The total number of blocks thus exceeded 100.

d) "When the programme of the tests was drafted out, the dates at which the results were to be ascertained should have been fixed at longer intervals during the first years, so as to be able, later on, to count upon a larger number of results."

It has been stated above, under b), that the raising of the cases was timed to take place after 3 and 6 months, 1 and 2 years etc. A period of ten years has elapsed, and there are still at each place two cases, which are to be raised after a total period of fifteen and twenty years. We may state for the guidance of those engineers who may wish to carry out similar tests, that in this respect a better arrangement could have been made.

e) "The chemical actions of salt-water are not alone able to deteriorate mortar; Portland cement appears to be almost intact."

Among the actions to which the cubes of mortar are exposed, the chemical action should have been most clearly shown by a comparison between the results of the exposure below the sea level at Degerhamn and those of the exposure in deep water at Esbjerg, there being between the two places only a difference in the percentage of salt in the water $3^1/_2{}^0/_0$ and $^1/_2{}^0/_0$.

Mr. Czarnomsky has stated that in the Black and Caspian seas, salt has a pretty marked effect on concrete. The percentage

[1]) A clayey Sand containing about $70^0/_0$ Silica found in the Island of Santorin, Greek Archipelago (Note Secr. Association).

of salt in both the latter seas, and the temperature of the atmosphere especially, are much higher than in Scandinavia. At those two places, therefore, the salt has a more marked effect, while on the Scandinavian coasts other actions, especially frost, prevail.

f) "On the other hand, the Teil lime was found to be subject to great chemical variations. The analysis at Vardo tends to show that a mechanical action may have hastened a simultaneous chemical decomposition."

As is well-known, the Le Teil lime has acquired a great renown in the French Mediterranean ports; it is there considered quite satisfactory and is almost exclusively used for constructions in the sea. The same for Italy in regard to pouzzolana and lime mortars, and this notwithstanding the high percentage of salt in the Mediterranean waters, 4%. Although these materials acquire after an exposure of about twenty years to the action of the sea a consistency similar to that of chalk, they are used with advantage.

In our more northern countries, Teil lime deteriorates relatively quickly, and, besides, a chemical effect has been noted; this is explained by a primary action of frost which by causing cracks on the surface, accelerates and increases the chemical action. Portland cements which acquire more rapidly a sufficiently high resistance to better withstand the mechanical effect of frost, appear for this reason to be, comparatively at all events, free from chemical actions.

In some cases, a granit facing with a grouting carefully maintained might act as a protection.

The poorer kinds of mortar were not sufficiently sheltered. They cracked and a white mass issued from the cracks. In some instances we found what are styled "tulipes de béton", strange formations (of which a few examples were shown at the meeting), which however, do not proceed from the test specimens, but from a groin of the dyke to the North of Thyboron, An explanation of this formation was given in a recent issue of "Cement and Beton."

g) "The deterioration of the mortar tests specimens was due mostly to the mechanical effect of frost."

In comparing the test specimens from Vardo with those from Esbjerg, and specially those that were placed at the average

sea level, a very great difference is found, although the water at both these harbours, contains practically the same proportion of salt, $3 \cdot 5^0/_0$ There is, however, a considerable difference in the climate of these two harbours, situated at a distance from each other, the average temperature of the atmosphere and of the water being 0^0 C (32^0 F.) at one place and $7^1/_2{}^0$ C (45^0 F.) at the other.

We have here the most important result of our tests, i. e., the predominating effect of a cold climate. Whilst at Esbjerg and at Degerhamn the test specimens kept pretty satisfactory for ten years, only a few from Vardo (which were shown at the meeting), have revealed a high resistance in the crushing test carried out at the Laboratory, a further proof of the supposition that the disintegration of the mortar cubes was not due to an internal chemical action, but to a mechanical effect on the surface.

h) "The deterioration of concrete blocks is also explained by climatic effects."

The blocks have been placed at Thyboron only; no comparison is, therefore, possible. It is hardly possible either, although an attempt has been made to do so, to note the chemical results produced. The analyses have shown, both in regard to the blocks and mortar cubes, that the amount of oxide has decreased. In certain instances, especially in the Teil lime, the proportion of magnesia and sulphuric acid has increased. There has always been found an increase in the quantity of chlorine which generally and from the analyses made for this, has no chemical connection with the alkali.

It should be remarked however that accurate analyses of a mortar, and more so of a concrete, are rendered very difficult by the foreign bodies which are introduced with the sand and the shingle; for this reason it is practically impossible to obtain exact figures. The appearance of the blocks is therefore the more reliable means for estimating deterioration.

i) "The 1 : 3 mixtures of mortar is too poor for use in the sea in Scandinavia."

Here, the word "sea" implies normal sea-water containing $3 \cdot 5^0/_0$ of salt; in the Baltic, weaker mixtures can no doubt be used if they be protected against frost.

In sea-water, specially at Vardo, our tests showed the 1:3 specimen of mortar to have much less durability; among the con-

crete blocks placed at Thyboron, those with 1:3 mortar were almost all destroyed after ten years.

j) "The sand used in mortars should be mixed sand of different degrees of fineness, the greater portion, however, being fine sand ($^1/_3$ to $^2/_3$); specimens having the denser mixture were not those which lasted longest."

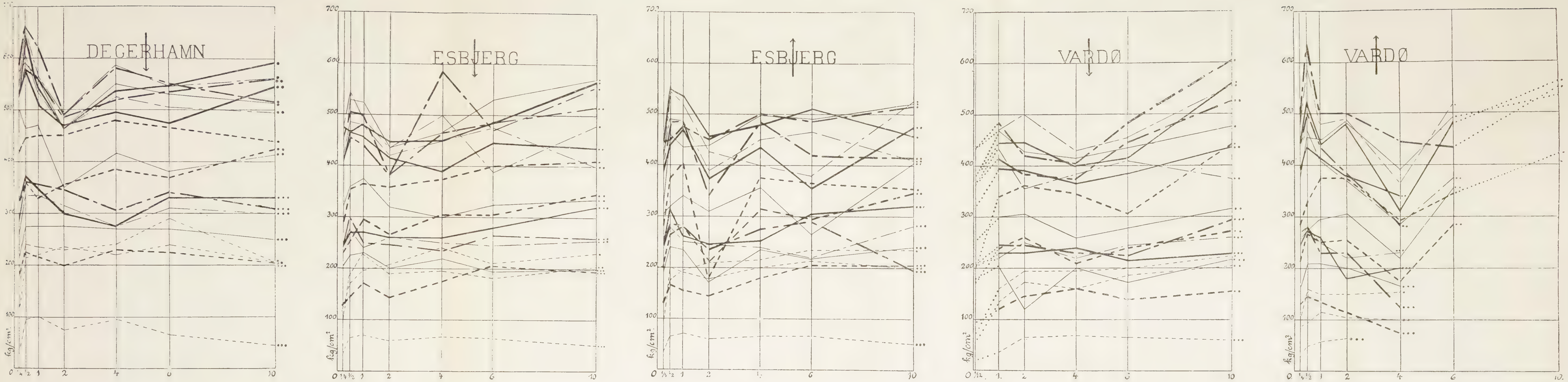
The coarsest sand in the mixtures is formed of particles of the size of grains of corn or barley; the finest is that of the local sand-hills and there is used also a sand of intermediate fineness. The denser mixture contains $^1/_3$ of fine and $^2/_3$ of coarse sand, with 24% water; it contains no sand of the intermediate grade. The mixture of $^1/_3$ fine with $^2/_3$ average fineness was found superior to all others in tests made elsewhere. In our Country the results bear upon a mixture having a larger proportion of fine grade (about half) and containing but coarse and fine sand.

k) "The addition to the cement of a material crushed fine (trass, or ordinary sand) is advantageous."

Our tests have confirmed former results, to the effect that mortar can be improved by adding to it various substances, crushed as fine as the cement itself. For us, however, this point has not the value which attaches to it in those countries where trass, or pouzzolana, is found, or where slag is produced. We have ascertained the value of ordinary sand, crushed with the cement ("sand cement"), and we have also made a test with an addition of Danish infusorial earth, the cheapest addition for us, the result of which is as yet doubtful.

In conclusion I may add that the tests in question mapped out to cover a period of twenty years have, so far, only covered half that period. The results, therefore, are not yet complete and cannot be considered as final.

Diagrams showing results of crushing tests of mortar cubes.



Resistance is given in kg per sq. cm, the values being for the number of years shown: one centimetre equals 50 kg per sq. cm, and one centimetre equals one year. The arrow in the name of the locality indicates whether the exposure was below or above low-water mark.

In each diagram are found 3 curves of similar design; which apply to the same class of cement. The one, two or three dots on the right hand border show the kind of mixture: 1 : 1, 1 : 2, 1 : 3.

Aalborg.
Aalborg with seashore sand.
Christiania.
Lomma.
Nine Elms.
Teil lime.

PROCEEDINGS

OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

Published at irregular intervals in an English, French and German edition. For Members gratis.

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Special notice.

President Charles B. Dudley †.

We have received from Philadelphia the painful news that our honoured President, Mr. Charles B. Dudley, passed away on the 21st instant.

Scarcely three months have elapsed since the Congress, amidst general enthusiasm, elected this much esteemed researcher to the highest position of honour in the gift of the Association, and since Mr. Dudley undertook this difficult office, full of confidence and vigour for work. His whole life had been spent in testing, he said, in the simple words of thanks addressed by him to the Meeting, and now as he was approaching the end of his work, the Association had conferred upon him the Presidency of their body, which he could not but regard as the greatest honour that had ever come to him.

It is a tragic stroke of fate that the old researcher, whose name will ever remain honourably inscribed in the annals of technical science, only enjoyed for so short a time the high distinction thus bestowed upon him by the fellow experts of his profession from all countries in the world.

For the Association itself it is indeed a most serious loss, that the work of the newly elected President should come suddenly to so abrupt a conclusion. From the moment when Mr. Dudley accepted the difficult office of President, he set to work with positively youthful ardour, to smooth all paths, so as to facilitate the future development of the Association, to make the attainment of its great aims possible, and to ensure the success of the coming Congress.

As a prominent researcher, as a clearsighted and untiring worker, and at the same time as a man both of touching goodness and of that fine simplicity which recalls the great men of American tradition — as such, the late President will continue to live in the memories of all who had the happiness of knowing him.

The Association will always hold him in grateful remembrance.

E. Reitler
General Secretary.

A. Martens
I. Vice-President.

Untill, according to the By Laws a Member of Council shall be nominated Acting President, the first Vice-president Professor A. Martens will act as provisional head of the Association.

FIFTH CONGRESS

OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

HELD IN COPENHAGEN FROM SEPTEMBER 7th TO 11th 1909.

REVIEW OF THE CONGRESS.

I. REPORTS LAID BEFORE THE CONGRESS.

II. DISCUSSIONS IN CONGRESS.

BY-LAWS AND MEMBERS' LIST OF THE ASSOCIATION.

ISSUED BY THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS, GENERAL SECRETARY'S OFFICE: 50, NORDBAHNSTRASSE, VIENNA II.

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The late Dr. Chas. B. Dudley †.

At the time the present papers were being printed, we received the very sad news that Dr. Chas. B. Dudley, whose election as president had been so unanimously welcome, had died at Altoona, on December 21st, after only a few days sickness.

Dr. Dudley was born on July 14th, 1842, at Chenango County, New York. His first studies were conducted at the local school and academy. He volunteered for service in the War of the Rebellion, and was dangerously wounded in one of the engagements. At the close of the war he went back to his studies, but was compelled to interrupt them for a time, in order to do journalistic and other editorial work, with the object of acquiring sufficient funds to follow the courses at Yale College. He devoted most of his time to the study of chemistry and graduated as Ph. D. in 1874.

After one year spent as assistent in the physical laboratory, Pennsylvania University, Philadelphia, he entered the service of the Pennsylvania Railroad as chemist. In that position he worked for the last thirty-four years — a period of most fruitful activity — at testing materials embracing the whole of the requirements of the Pennsylvania Railroad. He was the pioneer in America in regard to the institution and regulation of testing methods; his work formed the basis on which were established the specifications for the supply of material of all classes and the improvements carried out in the

manufacture of such material. He had become one of the most prominent technical experts of America, and his works received the approbation of the whole world; in this connection his researches on the relation existing between the physical and technical properties of rail steel and on the wear of steel rails, deserve a special reference, seeing that they are standard works which form a lasting record of considerable technical value.

The laboratory of the Pennsylvania Railroad offered to Dr. Dudley a wide field for research; his experiments played a most important part in the testing of materials throughout North America. For a long time he had been at the head of the powerful American Testing Association and had been deeply interested in working for the international unification of methods of testing. His appointment as President of our Association could therefore be considered as a crowning distinction, since the whole of his life had been devoted to testing; one of the results of his appointment would have been to allow him the most pleasing opportunity of extending his views and his great experience over an international field, to the great furthering of the cause of our Association, for which he had always showed the greatest regard.

His death has destroyed all these hopes; it is a most severe loss to the International Association and to the problem of material testing.

Nor is it in technical circles or on account of technical interests alone that this will be felt. Through the death of Dr. Dudley the world has grown the poorer by the loss of one of its noblest, one of its greatest-hearted men.

REVIEW OF THE CONGRESS.

The Vth Congress of the International Association for Testing Materials was held in Copenhagen from the 7th to the 11th of September 1909. It formed a most impressive demonstration of the importance of the scientific and technical problems which are dealt with by the Association. Some 900 members assembled for the Congress from all parts of the world, among them being most prominent representatives of scientific research and manufacture; the governments of 22 states sent official delegates; and the King of Denmark, by graciously accepting the office of Patron, and by personally taking part in the opening Meeting, gave public proof of his appreciation of the work of the Association.

On the eve of the Congress the Council of the Association and the Organising committee enjoyed the high distinction of joining the King and the Royal family at dinner, — on which occasion the King made the following important speech:

"I am highly pleased to be able to welcome in you, "gentlemen, the worthy representatives of the science of "engineering, which in less than a century has altered "the face of the world, which continues to alter it more "and more, and has made it possible to extend to all "mankind, including those men in the most humble "situation, the advantages of modern progress which until "now were the privileges of a small number of the rich "alone."

"I am greatly pleased at your selecting Copenhagen "for holding your Vth Congress."

"Although it is the capital of one of the small states "of Europe, you will find here a population seeking with "all its might to contribute to the progress of mankind, "and inspired by the noble and honourable desire of "attaining distinction in every department of science, art,

"and labour, where intelligence and energy are required. "It desires nothing so eagerly as to justify in this con-"nection its right to an individual existence, and to acquire "thereby the esteem and friendship of all other nations."

"I drink this toast, therefore, with the expression of "my warmest wishes for the success of your labours. "I trust that you will take away with you from Denmark "not merely the recollection of a hospitable reception, but "also the impression that the Danish people is contributing "in an able way to the great work of man's common "welfare and to the peace of the world."

In the reception which the King held after dinner he expressed in the course of conversation his regret at being unable to receive, through lack of space, all the members of the Congress.

The opening meeting of the Congress took place on the morning of September 7th in the great hall of the University.

Before the meeting, the delegates of foreign governments, whose visit had been notified through diplomatic channels, and the officers of the Council and Congress, assembled in the Consistorial hall, where the delegates were presented to the King and to the Crown Prince, who entered into conversation with them, while the other members of Congress gathered in the magnificent reception room every available seat in which was rapidly taken up.

The King and the Royal family attended in a state box during the ceremonial opening of the Congress. The Prime Minister, His Excellency Count Holstein Ledreborg; the honorary Congress members; the Minister for Home Affairs, His Excellency Klaus Berntsen; the Minister for Foreign Affairs, His Excellency Count Ahlefeldt-Laurvingen, and the Lord Mayor of Copenhagen, H. V. Oldenburg, as well as the Chancellor of the University Prof. Dr. C. Torp, were also present. The meeting was appropriately opened by a Cantata specially composed for the circumstance; this was sung with great effect by the Student's Choir. After this Crown Prince Christian of Denmark, Honorary President of the Congress, made a speech in which he welcomed the members assembled, and declared the Congress formally opened. The text of his speech, which was enthusiastically received, as well as the subsequent business report made by Mr. Alex. Foß, the President of the Association, and the paper read by Mr. Paul Larsen on

"The Development of the Cement Industry in Denmark", are given in full in the official report of the Congress. The ceremonial opening meeting was suitably concluded by the singing of a second cantata.

The work of the Congress was carried on simultaneously in three sections on the 8th, 9th and 10th in rooms set apart in the splendid new Townhall, from 9·30 a. m. to 2 p. m. All the reports printed in English, German and French, having been sent beforehand in good time to the members the meetings were almost exclusively devoted to discussions. These discussions were on the same high scientific level as the problems under consideration, and they led to a series of suggestions which in part found expression in the resolutions passed by the Sections. The resolutions indicate the lines to be taken by the work of the Association during the next few years.

The General Meeting of September 11th gathered all the members in the magnificent Assembly Room of the Town Hall, where the resolutions of the Sections were finally ratified, the holding of the VIth Congress in America decided upon, and Mr. Charles B. Dudley elected President. After the assembled members had expressed their warm gratitude to the organisers of the Congress and more especially to Mr. Foss, the retiring President who had been nominated life member of Council, Mr. E. J. Stead, Middlesborough, delivered a special lecture on the use of the microscope in metallurgy, illustrated by numerous lantern slides.

The Congress proceedings contain most detailed reports both of the meetings of Sections and also of the General Meeting. A new and most interesting means of assistance in recording the business of the meetings was found in Poulsen's Telegraphone, lent by the Dansk-Telegraphone-Company, a most interesting apparatus of Danish invention which registered with great precision the discussions in the three languages, and thus gave successful proof of its usefulness in large assemblies.

A small collection of special machinery was on exhibition in close proximity to the rooms used for the Congress meetings; this exhibition is specially referred to in the preface of the Congress proceedings.

Thanks to the excellent arrangements which had been carried out, the members of Congress and their ladies had the opportunity

of visiting in a very short time a number of interesting installations both in Copenhagen and in its vicinity.

The visitors also derived much interest and instruction from a series of visits paid to Carlsberg breweries, to the new free port; they also inspected the admirable arrangements for traffic at the main railway station, the machinery- and ship-building yards of Messrs Burmeister and Wain, the Elsinore ship-building yards, the refuse-destruction plant, and the electric-power plant at Frederichsberg. Director Hagemann exhibited the excellent arrangements of the Technical College, while Professor Hannover, a kindly host, received the numerous expert visitors in the fine Testing Laboratories; he distributed among the members of the Congress a nicely got up booklet which records the work done by the establishments under his charge. This booklet also gives instructive information on the great share which the Scandinavian countries have, from the first, taken in the development of Testing materials.[1])

The inspection of the castle of Christiansborg, now in course of construction, a visit to the picturesque and historical castle of Kronborg, a trip round the harbour, a visit to the celebrated and much admired Royal Porcelain Works, in which the artistic porcelain Congress badge, was made and finally, a visit to the new Carlsberg Glyptothek enabled the visitors to form an adequate opinion of the beauty of the town and of the richness of its countless art treasures. Special visits were arranged for the ladies during the Sectional meetings; these were made to the Art and Industry Exhibition, the Thorwaldsen Museum, the Castle of Rosenborg and the Hagemann Students' Home. A motor-trip was also taken to see the dairy of "Trifolium" near Haslev.[2])

The favourable impressions gained each day were completed in the evening by a series of entertainments which, by the heartiness of the reception afforded, the charm of the ladies, and the exceedingly happy arrangement of every detail, delighted the numerous guests. In the evening of the opening of Congress, the Danish Engineers Association under their President, Professor Steenberg,

[1]) On the Development of the Science of Testing Materials in Scandinavia; also recording the Work of the State Testing Institute in Copenhagen.

[2]) A special Congress number of the periodical "Illustredet" Tidende with abundant illustrations was given as a souvenir to the members.

gave a brilliant reception to the visitors at the Royal Shooting Club, a reception which took the shape of a most charming garden-party. The following evening, Mr. Oldenburg, Chief President of the Copenhagen Municipality, with the mayors and aldermen, received the visitors in the splendid apartments of the Town Hall; this, with its striking covered courtyard, surrounded by splendid galleries, formed an absolutely ideal festive hall. A gala-performance of the highest artistic order was given at the Theatre Royal; this was graced by the presence of the Queen and membres of the Royal Family.

The days of festivity were brought to a close by a steamer trip to the charming watering-place of Skodsborg, where the members of Congress met informally for a dinner, and by a trip on the coast Railway, through a picturesque district to the magnificent watering-place of Maryenlist, where the numerous visitors were entertained to a farewell-banquet.

Some hundred members of Congress, under the guidance of President Foss, undertook the great four-days final excursion to Jutland, the object of which was the inspection of the Portland cement Works in Aarhus, and of the splendid seawalls on the west coast of Jutland.

This excursion, favoured during the sea-trip by most magnificent weather, and delightful from the charms of an all but unknown country, delightful also owing to the admirable travelling-arrangements made by the indefatigable Captain Petersen, will long be remembered by all who took part in it, as one of their most enjoyable pleasure-trips. — A special steamer, the "Melchior", provided the party, of an evening, with a comfortable home, and carried them on by night, as if by magic, to a series of ever new scenes and shores.

On the first morning, September 13th, the party found themselves at Skagen, the interesting northernmost point of central Europe, where the currents of the Skagerak and Kattegat, meet in a mighty rush whose beauty proved so inspiring to the Danish painters, Kröyer and Anchert and to Holger Drachmann, the poet, who lies buried on the headland, close by.

The West-coast, beaten by the surf of the Skagerag and the North Sea, commences at Skagen. Masses of wreckage beaten to and fro by the waves testify to the dangers which surround the

headland. A most interesting performance was carried out during the visitors' stay, the heroic lifeboatmen having launched and manned their boat.

Under the kind guidance of M. Richter the mayor, and his wife, the excursionists were able to admire in the course of an extensive drive, the particular views offered by the downs the fine sand forming which had been for centuries a danger to the neighbouring villages, actually burying some of them, until plantations made within the last years had succeeded in helping to keep it in check. — One great shifting sandbank alone, the Raabjeg Mile, consisting of the finest white sand, still keeps alive the memory of the strange forces of nature which once wielded such limitless power in this district.

A short voyage in the night brought the party to Aalborg, where the interest of the spectators was absorbed by the Hörresundby and Aalborger Portland-Cement Works with their splendid modern appliances, the "kominors", revolving furnaces, and the great quarrying work in the huge chalk cliffs. A new type of pneumatic filling-apparatus for sacks, — by means of which the cement-powder is poured down in a vacuum into the sacks without need of further assistance, — attracted particular attention on account of the exactness of this method of filling, and the complete absence of dust. In the course of a luncheon on the lawn, characterised by good-fellowship and abundance, opportunity was afforded for thanking Mr. Berg, the manager, for his friendly reception.

On the following morning the "Melchior" arrived in magnificent weather at the thousand-year-old, historical town of Aarhus. Under the guidance of Dr. Winge, the President of the Jutland Tourist Club, the old cathedral, of high artistic interest, was visited and greatly admired, as also were the modern art gallery and other public institutions, and the splendid beech-wood in Marselisborg. The National Exhibition, charmingly situated near the beach, received a large share of the visitors' attention. The exhibition bore witness in its numerous tasteful buildings to Denmark's many-sided industries, to the riches of its agriculture and the high standard of its art; the most striking part of all was that formed by the models for the erection of artistic dwellings in the station-road of a village. A banquet, given by the municipality of Aarhus,

under the chairmanship of the Mayor, Mr. Drechsel, concluded the visit.

A night's railway journey brought the remainder of the party to the west coast of Jutland for the inspection of the sea-walls there, particularly at Bovbjerg, where the sandy coast, some thirty feet high, had been encroached upon for years by the heavy beating of the sea-waves, until this encroachment was checked by the successful erection of sea-walls. Here the guidance was undertaken by Mr. Poulsen, who had written for the Congress a report upon the experiments carried out on a large scale by the Association of Scandinavian Portland-Cement Manufacturers as to the effects of sea-water upon cement.[1] From Bovbjerg a series of 70 breakwaters cross the peninsula north of Limfjord; these have cost up to the present time a total sum of 15 million Francs. A carriage-drive through the softly undulating country with its scattered farms, each having on its roof a wind-motor, a token of progress in farming, and then a short railway trip, brought the party finally to Thyborön for an inspection of the experimental breakwaters of cement-blocks in which the most varied cements, admixtures, and sands have been used, in order to test their suitability for building purposes on the sea coast.

After this, the party made their way back to Lemvig, the final goal of the excursion. Here, at a farewell supper, the gratitude felt by the visitors was again openly expressed; most cordial thanks were given to the organisers of the Congress, above all to President Foss, the indefatigable Captain Petersen, to Messrs. Lorenz and Hannover, and the ladies of the committee.

A most complete success can be recorded for the Vth Congress in every respect. It has very considerably contributed towards the appreciation and propagation of the aims of the Association. Its proceedings will provide for years to come valuable matter which will forward the work of the Association. It has moreover left in the mind of all who took part in it a large amount of most delightful recollections.

The newly elected President of the Association, Mr. C. B. Dudley, has expressed the great gratitude which the Association

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[1]) "Cement in Seawater". Report upon Experiments organised and being carried on since 1896 by the Association of Scandinavian Portland-Cement-Manufacturers. By A. Poulsen. Gad Publishing House. 3 frs. Copenhagen 1909.

owes to the organisers of this Congress by the following letter addressed to Mr. Foss, the President of the Congress, a letter which, so far as mere words are able to do reflects the feelings of all the visitors.

"My dear Sir, It is with feelings of inward satisfaction "and sincere pleasure that all those who took part in the "Congress at Copenhagen look back upon the delightful "days spent in that city. Each of them has carried away "with him the proud consciousness of having been witness "to a stirring manifestation of intellectual activity, such as "does not pass away with the day, but will be powerfully "efficacious towards the accomplishment of those ends "aimed at by the Association."

"The scientific results of the Congress would not "have been possible without the splendid organisation "which we owe, my dear Sir, to you and to the various "Committees under your presidency. Your powerful appeal "called together the first experts of the whole world, and "gained members to take part in the Congress from distant "countries which had till now been wholly ignorant of the "Association and its objects."

"By means of this Congress the number of the adherents of the Association has been as much increased "as the general understanding of its scope and intention "has been deepened and widened."

"Not only, also, did you succeed by means of your "well-planned organisation in giving clear aim and direction "to the willing work of hundreds, but you likewise understood how to display, in a short time, the rich treasures "of your beautiful country after a fashion unforgettable "to all."

"The Congress members have learnt in Denmark to "admire with their own eyes a country standing, through "its own high culture, in one rank with the first civilised "nations of the world, a country dedicated to the furtherance "of public prosperity under the wise rule of a sovereign, "himself a lover of progress."

"We beg you therefore, my dear Sir, to accept the "most sincere and cordial thanks of the Association and "to convey the same to all those kind cooperators, both "ladies and gentlemen, who have given you their assistance "in this laborious work."

"May the consciousness of having powerfully promoted "the objects of the Association and of having gained new "friends for Denmark in every part of the world be the "true reward of your great and unselfish labours!"

"With the expression of the highest esteem,"

"The International Association for Testing Materials."

Ernst Reitler,
General Secretary.

Charles B. Dudley,
President.

FIRST PART.

REPORTS PRESENTED TO THE CONGRESS.

LIST OF PAPERS.

A. METALS.

Metallography.

I1 Report on Progress made in Metallography from the Brussels Congress up to the Commencement of 1909. By Prof. **E. Heyn**, Groß-Lichterfelde.
I2 Special Steels. By Prof. **Léon Guillet**, Paris.
I3 The Heat Treatment of Spring Steel. By **Lawford H. Fry**, Paris.
I4 "Slag Enclosures" in Steel. By **Walter Rosenhain**, B. A., D. Sc., Teddington.
I5 On the Homogeneity of Metal. By **G. Tagueeff**, St. Petersbourg.

Hardness Testing.

II1 Hardness Test. Official report by Dr. **P. Ludwik**, of Vienna.
II2 Simplified Ball-Hardness Testing Machine and Results obtained therewith. By Prof. **A. Martens** and **E. Heyn**, Gr.-Lichterfelde W.
II3 The Cone-Pressure Test for Determining the Hardness of Permanent Way Materials. By Dr. **August Geßner**, Vienna.
II4 Investigations on the Brinell Method of determining Hardness. By **Harold Moore**, B. Sc., Woolwich Arsenal, England.

Impact Tests.

III1 Official Report on Impact Tests of Metals. By **G. Charpy**, Montluçon.
III2 On Notched-Bar Impact Bending Tests. By Prof. **F. Schüle**, in conjunction with **Ed. Brunner**, of Zürich.
III3 The Definition of Resilience in Impact Tests. By **Louis Révillon**, Paris.
III4 Impact Tests at variable Temperatures. By Prof. **Léon Guillet** and **Louis Révillon**, Paris.
III5 Impact Tensile Tests. By **Pierre Breuil**, Paris.
III6 Application of Modern Testing Methods to Copper Alloys. By Prof. **Léon Guillet** and **Louis Révillon**, Paris.
III7 Comparative Static and Dynamic Notched-Bar Bending Tests. By Dr. **A. Leon** and Dr. **P. Ludwik**, Vienna.
III8 Note on the Rupture of Normal Cylindrical Test Samples by Longitudinal Impact. By **P. Wélikhow**, Moscow.

Testing Metals by Alternating Stresses.

IV1 The Endurance of Steels to Repeated Alternate Stresses. By **James E. Howard**, Watertown, Mass., U. S. A.
IV2 Quality Tests and Endurance Tests of Copper Wires. By Prof. **F. Schüle** and **E. Brunner**, Zürich.

Testing of Cast Iron.

V1 Report in connection with the Tables of Results of Experiments on the Strength-Properties of Cast-Iron of various Sections taken from separately-cast samples and from samples cut out of castings. By **Brothers Sulzer**, Winterthur, Switzerland.
V2 On Uniform Methods of Testing Cast Iron. Official report presented by Dr. **R. Moldenke**, New-York, Chairman of Committee 25.

Influence of Increased Temperature on the Mechanical Qualities of Metals.

VI 1 **Official Report** by Prof. **M. Rudeloff,** Groß-Lichterfelde W.

Magnetic and Electric Properties of Materials in Connection with their Mechanical Testing.

VII 1 **The Utilisation of the Magnetic and Electric Properties of Materials in conducting Mechanical Tests.** Report by **A. Grünhut** and Dr. **J. Wahn,** Vienna.

VII 2 **Ferromagnetism and the Study of Metals and Alloys.** By Prof. **Pierre Weiss,** Zürich.

VII 3 **Method for Determinig Elastic Strength Limit by Means of Thermo-electric Measurements.** By **Ew. Rasch,** Gr.-Lichterfelde.

Committees' Reports.

VIII 1 **Establishment of International Specifications for Iron and Steel.** Report of the Subcommittee Ia presented by the chairman of Committee I, Dr. Ing. **A. Rieppel,** Nürnberg.

VIII 2 **On the Uniform Nomenclature of Iron and Steel.** Report of Committee 24. Presented by Prof. **Henry M. Howe,** Chairman, New York, and Prof. **Albert Sauveur,** Secretary, Cambridge, Mass.

VIII 3 **On Standard Specifications for the Purchase of Copper.** Report of the Copper Committee 38, by the Chairman Mr. **Léon Guillet,** Paris.

Various reports.

VIII 4 **A New Mirror Apparatus for Measurements of Elasticity.** By Professor **B. Kirsch,** Vienna.

VIII 5 Not appeared.

VIII 6 **Unification of Methods for Testing Steam, Gas and Water Pipes.** By **A. C. Karsten,** Copenhagen.

VIII 7 **Sparks as Indications of the Different Kinds of Steel.** By **Max Bermann,** Budapest.

Internal Strains.

VIII 8 **On the Principles of "Technological Mechanics".** By **Dr. Paul Ludwik,** Vienna.

VIII 9 **Internal Friction in Loaded Materials.** By **G. H. Gulliver,** B. Sc., Edinburgh.

VIII 10 **On irregular Strains due to Nonhomogeneity of Materials.** By Dr. techn. **A. Leon,** Vienna.

VIII 11 **Connection between the Permanent Sets caused by Traction and Compression.** By Dr. **William Misángyi,** Budapest.

VIII 12 **Tenacity and Malleability.** By Dr. **William Misángyi,** Budapest.

B. CEMENT, STONES, CONCRETE.

Reinforced Concrete.

IX 1 **Report of the Committee on Reinforced Concrete.** Presented by the Chairman of Committee No. 41, Prof. **F. Schüle,** Zurich, with the following appendices.

a) **Wissenschaftliche Versuche und Versuche zur Kontrolle der Bauausführung auf dem Gebiete des Eisenbetonbaues in Deutschland.** Mitgeteilt vom Deutschen Ausschuß für Eisenbeton, Berlin.

b) **Expériences et essais de contrôle sur le béton armé en Italie.** Rapport de M. le prof. **J. Benetti,** Bologne.

c) **Eisenbetonversuche in Dänemark.** Mitgeteilt von Prof. **E. Suenson,** Kopenhagen.

d) **Versuche mit Eisenbeton-Konstruktionen in Holland.** Mitgeteilt von **S. J. Rutgers,** Rotterdam.

e) **Recherches expérimentales sur le béton armé en Suisse.** Rapport de M. le prof. **F. Schüle,** Zurich.

IX_2 **Reinforced Concrete Structures. Measure of the Deformations of Structures under Service Conditions.** Appendix to Committee Report 41 by **Charles Rabut,** Paris.

IX_3 **Casualties in Reinforced Concrete Building.** Appendix to Committee Report 41 by Dr. **Fr. v. Emperger,** Vienna.

IX_4 **Influence of repeated Loading upon the Adhesion between Concrete and Iron, of bright, and of rusty surfaces.** By Prof. **Bernhard Kirsch,** Vienna.

IX_5 **The Influence of Small Sectioned Transverse Ties on the Strength of Concrete. System of Free Ties.** By **W. P. Nekrassow,** St. Petersburg.

Progress in the Methods of Testing.

X_1 **Progress in the Methods of Testing Hydraulic Cements.** Official report presented by **R. Feret,** Boulogne-sur-mer.

X_2 **Uniform Tests of Hydraulic Cements by Means of Prisms. Standard Sand.** Report of the Chairman of Committee 42 Prof. **F. Schüle,** Zürich.

X_3 **On Accelerated Tests of the Constancy of Volume of Cements.** Report presented by the Chairman of Committee 32, **Bertram Blount,** F. I. C., London.

X_4 **On Rapid Methods for Determining the Strength of Hydraulic Cements.** Committee-Report 9 presented by Dr. **Fr. Berger,** Vienna.

X_5 **Note on the Rapid Testing of Cements treated with hot water.** Appendix to report X_4 by **L. Deval,** Paris.

X_6 **On Rapid Methods for Determining the Strength of Hydraulic Cements.** Appendix to report X_4 by **Alfred Greil,** Vienna.

X_7 **Determination of the Simplest Method for the Separation of the Finest Particles in Portland Cement by Liquid and Air Processes.** Report of Committee 30. By Prof. **M. Gary,** Gr.-Lichterfelde.

X_8 **Appendix to Report X_7 by Mayntz Petersen,** Copenhagen.

X_9 **Unification of Specifications for Gypsum.** By Prof. **M. Gary,** Gr.-Lichterfelde, and **R. Feret,** Boulogne-sur-mer

X_{10} **Testing Puzzolanas with the Object of Determining their Value for Mortars.** By **G. Herfeldt,** Andernach.

X_{11} **On the Best Manner of determining the Commencement and the Time of Setting.** Hardness Test, by **H. Laborbe,** Paris.

X_{12} **The Setting of Roman and Portland Cement as paste, in mortars and concrete.** By order of the Hungarian Society for Testing Materials, presented by Prof. Dr. **Const. Zielinski,** Budapest.

X_{13} **Proposal Made by Mr. Mayntz Petersen in Copenhagen on the Alternation of the Methods of Testing Recommended by the IV^th^ Congress.**

Cement in Sea Water.

XI_1 **Experiments on the Decomposition of Mortars by Sulphate Waters.** By **J. Bied,** Le Teil (Viviers, Ardèche).

XI_2 **On the Condition of the Cement Blocks in some of the Russian Ports in the Black and Caspian Seas.** By **W. Czarnomski,** St. Petersburg.

XI_3 **The Use of Reinforced Concrete beside the Sea.** By Prof. **M. Möller,** Brunswick.

XI_4 **Cement in Sea Water.** By **A. Poulsen,** Copenhagen.

Weathering Resistance of Building Stones.

XII_1 **Wheathering Resistance of Building Stones.** Committee-Report 7 by Prof. **A. Hanisch,** Vienna, with the following appendices.

XII_2 **Schemes for Testing Natural Building Stones as to their Weatherproof Qualities.** By Professor Dr. **J. Hirschwald,** Berlin.

XII3 Relating to the Theory of the Influence of Frost on Natural Stones. By Prof. Dr. **H. Seipp**, Kattowitz.
XII4 The Determination of the Gelivity of Stones. Report by **E. Leduc**, Paris.

Various Reports.

XIII1 The Bonding of Layers of Mortar after Different Time Intervals. By Prof. **B. Kirsch**, Vienna.
XIII2 Notes on Trass, Trass-Cement and Cement-Lime mortars. By Dr. techn. **Heinrich Renezeder**, Vienna.
XIII3 Contribution to Methods of Investigation into the Elastic Longitudinal Deformation of Concrete. By Dr. **B. v. Bresztowszky**, Budapest.
XIII4 The Consequences of the Use of Mortar of Improper Composition. By Prof. **J. A. v. d. Kloes**, Delft.*)
XIII5 On the new German Standards for the Uniform Delivery and Testing of Portland-Cement. By **M. Gary**, Gr.-Lichterfelde.*)

C. SUNDRIES.

Oils.

XIV1 Official Report by Dr. **M. Albrecht**, Hamburg.

Caoutchouc.

XV Methods of Testing Caoutchouc. By **E. Camerman**, Brussels
XV1 Mechanical Testing of Caoutchouc. By **P. Breuil**, Paris.
XV2 Contribution to the Question of the Mechanical Testing of Soft Rubber. By **K. Memmler** and **A. Schob**, Gr.-Lichterfelde W.

Wood.

XVI1 Abstract of Report on the Present Status of Timber Tests in the Forest Service, United States Department of Agriculture. By Prof. **William Kendrick Hatt**, Lafayette, Ind., U. S. A.

Paints on Metallic Structures.

XVII1 On the Corrosion of Iron in Water and Aqueous Solutions. By Prof. **E. Heyn** and Prof. **O. Bauer**, Gr.-Lichterfelde.
XVII2 On Preservative Coatings for Iron and Steel. Résumé of Work done by the American Society for Testing Materials. Presented by **S. S. Voorhees**, Washington D. C.
XVII3 A Study of Rust-Preventing Paints for Metal Structures. By **Em. Camerman**, Brussels.
XVII4 A Plea for International Investigation concerning Protective Coatings for Iron and Steel. By **J. Cruickshank Smith**, B. Sc., London.

Papers.

XVIII1 On repeated stresses on papers. By Prof. **A. Rejtő**, Budapest.

General Matters.

XIX1 Testing in the Domain of Automobile Work. By Dr. **W. Exner**, Vienna.*)
XIX2 On the international Regulation-By-Law of Technical Testing. By Dr. **W. Exner**, Vienna *)
XX Business Report for the Period from the IVth to the Vth Congress.

*) Short abstract of the Report verbally submitted.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

VTH CONGRESS, COPENHAGEN 1909.

I5

ON THE HOMOGENEITY OF METAL.

Abstract of a paper by Mr. **G. Tagueeff**, St. Petersburg.

In applied mechanics and in the theory of elasticity, bodies are considered parallely homogeneous, isotropic, and having a mass which is continuous. But since, in reality, metals having a complex texture, are commonly non-homogeneous and have not a continuous mass, it is very important to ascertain the influence which these factors have on the behaviour of metals in actual practice. Microscopical investigations of the texture of metallic bodies which have undergone stresses exceeding the elastic limit, show that the non-homogeneity of the texture, or the permeations of foreign substances into the homogeneous mass, have a great influence upon the distribution of stresses in the transverse section.

Homogeneity is only a relative property; it is dependent upon the distribution of the elements at the different points of the metal and is thrown-up in the highest degree by the texture. The study of the texture is, therefore, the most complete and the most suitable method of ascertaining homogeneity.

The resistance shown by specimens subjected to various tests and the wear of the metal in actual service — although this latter has not a complete analogy with the results of laboratory experiments — depend upon the absolute properties of the metal (chemical composition and texture) and upon a relative property which is governed by the distribution of the elements in the mass of the metal and is called homogeneity.

When the normal resistance of tests specimens and of mechanical parts decreases suddenly, this can always be accounted for by peculiarities in the texture, by non-homogeneity. This

shows the great importance which attaches to the study of the homogeneity of metals. The influence of homogeneity is particularly evidenced by stresses beyond the elastic limit, close to the breaking strain.

If we consider a piece under a static load, the non-homogeneity of the metal has its origin at surfaces which separate from each other masses having a different elasticity. The extension of particles of the metal against these surfaces ceases at a given moment to continue in accordance with the law on the continuous function of tension and elongation, and from that moment each particle is under two claims which make for elongation and which, as they cannot be met, result in the fracture of the piece.

In the case of a piece under a dynamic action, the vibrations do not propagate in regular undulations, as would be the case were there to be perfect homogeneity, but at different velocities: there occurs interference in the undulations, hence two contrary velocities of different sign may be at play at any given point, leading to fracture.

The above remarks on homogeneity are confirmed by tests with rails, axles, etc., removed from the service in a good or bad state of wear.

I beg to state here a number of propositions which may be of interest and were deduced from special researches in the matter.[1])

1. The study of the flexion of rails by calculation or by the direct measurement of deformations does not explain the great difference found in the wear of rails, nor the deteriorations which occur in them.

2. Microscopical investigations have revealed

a) the existence of strains in the rail heads, which are explained by the non-homogeneity of the metal and which have considerably exceeded the calculated strains due to flexion;

b) the particular influence of the action of shock, leading to the fracture of a rail in the track, fracture which also depended upon the degree of homogeneity of the metal.

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[1]) "The homogeneity of rails." A supplement to the work of the Russian Committee for the study of rails. G. Tagueeff, 1908, St. Petersburg.

"The study of texture as a method of testing." (The homogeneity of the metal. Report to the Imperial Russian Technical Society, St. Petersburg, May 29th 1909.)

3. The wear of rails depends upon the properties of the steel: chemical composition and texture, also upon another property called homogeneity which latter is defined by the distribution of the elements in the steel.

4. The influence which homogeneity has in regard to rails is much more pronounced than that of the quality of the metal itself.

5. When the question is asked as to which is the best quality of steel for rails (reference being made to chemical composition and texture) having regard to the conditions of service, it is absolutely necessary to compare together rails equally homogeneous and subject to equal service conditions. This may be achieved by the laying of an experimental track.

6. The degree of homogeneity of the steel can be taken as a basis for classifying rails according to their life in service.

Rails of non-homogeneous steel are always either fragile or worn, or have yielded under the stretching strain, according to the character and local condition of non-homogeneity in each particular case; no very clear line of demarcation can, however, be laid down for establishing a distinction among isolated groups of bad rails.

Blow-holes and gas enclosures lead to the wear of rails; ghost-lines (decarburised surfaces of ferrite with permeations of foreign substances in the centre), make for fragility; and an unequal distribution of ferrite and pearlite leads to the yielding of the steel under stretching strains.

The MnS is absolutely detrimental from the point of view of resistance so long as it is present in accumulated masses, with the simultaneous occurence of cracks.

7. The cause which makes for non-homogeneity is due to the processes of manufacture of the metal before rolling (bath, teeming, reheating of ingots), or to the process of rolling, or can be traced to the cooling-down after rolling. The rolling hot of a rail which is allowed to cool-down slowly, throws-up the non-homogeneity of the cross-section, and decreases the technical properties of the steel.

The non-homogeneity of rails rolled hot is shown by the predominence of ferrite round the periphery of the cross-section; by the difference in the size of the grain and by a decrease in

the elastic limit in the steel taken from the central portion of the head.

8. The degree of homogeneity may be determined by a change occurring in the mechanical properties, in the limit of elasticity for example; this appears to be the best available means for tracing what the treatment of the metal has been.

9. The calculation of the coefficients of non-homogeneity of rails in their cross-section, based on the above, shows that:

a) Satisfactory conditions of wear for rails are hardly to be expected unless there be a sufficient margin of homogeneity.

b) The stetching strain of rails is proportional to the non-homogeneity of the cross-section.

c) The cœfficient of non-homogeneity of rails "strain stetched" is 5 to 15 times greater than that of rails which have maintained their section in service.

d) The homogeneity of rails which have proved satisfactory in service is 5 times higher than that of "strain stretched" rails.

10. Investigations in regard to texture make it possible to determine a few typical examples. For instance, the signs of a really bad service of steel pieces, shown by the ramified texture of pearlite of mild, and semi hard steel of axles and rails.

Errata of the report VIII$_2$:

ON THE UNIFORM NOMENCLATURE OF IRON AND STEEL.

By Prof. **Henry M. Howe**, New York, and Prof. **Albert Sauveur**, Cambridge (Mass.).

For Pontiloff p. 2 line 16 read Poutiloff
„ based on error p. 4 line 28 read based on an error
„ therm p 4 foot note line 6 read term
„ slaglees steel p. 9 line 12 read slagles steel
„ entectoid p. 12 line 20 read eutectoid
„ nickel, is austenitic, even p. 12 line 29 read nickel is austenitic even
„ pearlite. p. 15 line 8 read pearlite does.
„ almost p. 15 line 11 read about
„ cold steel p. 15 line 14 read cold carbon steel
„ constituent of steel p. 15 line 18 read constituent of carbon steel
„ lamellas p. 15 line 27 read lamellae
„ polyhedric p. 16 line 34 and 37 read polyhedral
p. 17 leave out: German: Merkantileisen
Spanish: Hierros comerciales
Italian: Verghe mercantili (barre da commercio)
For to them p. 18 line 20 read to it

SECOND PART.

DISCUSSIONS IN CONGRESS.

CONTENTS OF SECOND PART.

PREFACE.

This second part of the report on the Congress forms a survey of the organisation, the membership and discussions.

The latter took place at two General Meetings and at a number of meetings of sections. Mr. Alex. Foß, President of Council, acted as Chairman of the general meetings. A bureau was formed to conduct each section; this consisted of a chairman and several secretaries who most kindly undertook their difficult duties. The bureaux were as follows:

Section A (Metals):

Chairman: Mr. O. Busse, Director, Danish State Railways.

Secretaries: Mr. R. Christiani, Engineer; Mr. G. N. Knub, Engineer; Mr. Ove Munck, Chief Engineer; Mr. O. K. Ovesen, Chief of the Artillery Testing Dept.

Section B (Cement, Concrete and Stone):

Chairman: Captain T. Grut, Corps of Engineers.

Secretaries: Mr. O. H. Arboe, Engineer; Mr. Jul. Mathiesen, Engineer; Mr. Axel Schäffer, Engineer; Mr. H. E. Stenbjörn, Engineer.

Section C (Sundries):

Chairman: Captain B. Münter, Royal Navy, retired.

Secretaries: Mr. H. P. Bonde, Engineer; Mr. A. Jacobsen, Engineer; Mr. Mayntz Petersen; Prof. E. Suenson.

The Hon. Chairman and Hon. Secretaries, whose names President Foss announced at the first general meeting (see pp. 45—48), kindly gave the various bureaux their support; this was most welcome, especially in regard to translation work in the course of the discussions, as these were carried out in the three

languages. In this connection, besides the names of the Chairmen, may be specially mentioned those of Prof. F. Schüle, Prof. P. Weiss, Dr. W. Rosenhain, Messrs. Em. Hiertz, Edw. O. Sachs, G. C. Lloyd and J. Mathiesen.

The secretaries in each of the three sections took note of the main points raised in the course of the discussions. The latter were recorded in full by telegraphones which had been placed at the disposal of the Congress by the Dansk Telegraphon-Aktieselskab, Copenhagen; these instruments gave complete satisfaction. Several of the speakers were also kind enough to send in abstracts of their remarks.

The whole of the matter has been edited in the General Secretary's office and abridged where necessary.

The reports published by the Council had been sent, previous to the date of Congress, to all members. These reports are given in the First Part of the Proceedings.

During the time the Congress was being held, a number of papers were distributed to members by their authors or publishers; the following is a list of the same:

On the Development of Material Testing in Scandinavia and on the work of the Danish Government Testing Laboratory, Copenhagen, offered by the Laboratory.

Cement in sea water. Report upon the tests commenced in 1896 by the Association of Scandinavian Portland Cement Manufacturers. By A. Poulsen Royal Danish Hydraulic Works Dept.

Note on Abrasion Tests for Metals. Note concerning certain experiments with alternating Pressures, by E. Nusbaumer, Engineer, Laboratory of the G. Derihon Works, Loncin near Liége, Belgium.

Note by **Mr. A. Pourcel and Mr. A. Greiner** following the report of Committee 24.

Results of Comparative Tests with Portland Cement carried out in 1909 in Amsterdam, Karlshorst and Zürich on the usual, and the prism methods (German).

Lists of Tests with Concrete and Reinforced Concrete made in the German Testing Laboratories of Brunswick, Dresden, Gr.-Lichterfelde and Stuttgart (German).

Report by Prof. Talbot on Reinforced Concrete Tests made in the United States.

Slag Cement by Engineer Giulio Bellotti, abstract of tests made by the Florence Technical Institute (French).

Experiments upon the Decomposition of Cements in water sulphates by Mr. J. Bied. Abstract from the "Revue de Métallurgie" (French).

Second report upon the maintenance of Hydraulic Bonding Material in sea water, applying to tests made by the Royal Testing Laboratory, Gr.-Lichterfelde, with the cooperation of the Royal Hydraulic works Inspection Dept.,

Husum, by Prof. **M. Gary** and Engineer **C. Schneider.** Reprint from the "Mitteilungen aus dem Königlichen Materialprüfungsamt", Gr.-Lichterfelde, 1909, nos 5 and 6 (German).

Report of Committee "E" on Preservative Coatings for Iron and Steel. Havre de Grace Bridge Test including Analysis of Paints and analytical Method by **P. H. Walker** and **P. C. Mc. Ilhiney.** Reprint from the Proceedings of the Am. Soc. Test. Mat. Philadelphia, Penna. Volume VIII, 1908. Scientific Section Paint Manufacturers Association, Philadelphia, Pa.

Contribution to the Question of Mechanical Testing of Soft Rubber. I. On the influence of the shape of specimens on the results. By Dipl. Engineer **K. Memmler** and Engineer **A. Schob.** Proposed by the "Königl. Materialprüfungsamt", Gr.-Lichterfelde; for the Vth Congress, Copenhagen, Sept. 1909, of the International Association for Testing Materials (German).

Technological Mechanics, by Paul Ludwik. Reprint from the "Österr. Wochenschrift für den öffentlichen Baudienst", 1908, no 42, page 762 (German).

"Illustreret Tidende", special issue, offered to the Members of Congress.

In connection with the Congress a small

exhibition

was held of special machines for testing, which proved of great interest.

It contained the following:

An apparatus for hardness testing by means of a sharp edged disc, exhibited by the Engine Department of the Danish State Railways, by Director Busse, Copenhagen.

A new mirror for measuring elasticity, by Prof. B. Kirsch, Vienna.

A rebound-meter and hardness testing apparatus on the Brinell and Ludwik principles, shown by the Aktiebolaget Alpha, Stockholm.

An Automatic cement screening machine, exhibited by Messrs. F. L. Smidth & Co., Copenhagen.

Machines for testing soft rubber, viz. a Schopper-Martens machine for duration tensile tests and a Schopper-Martens machine for breaking-strain tests (see "Mitteil. aus dem Kgl. Materialprüfungsamt" Gr.-Lichterfelde, 1909, p. 173), shown by Mr. Louis Schopper, Leipzig.

A microscope for metals, exhibited by M. C. Reichert, Vienna.

Vienna, January 1910.

Ernst Reitler,
General Secretary.

Patron:

HIS MAJESTY THE KING.

Honorary President:

HIS ROYAL HIGHNESS THE CROWN PRINCE.

Honorary Members:

Comte C. W. Ahlefeldt-Laurvigen, Secretary for Foreign Affairs.
J. C. Christensen, Secretary for Defense.
Klaus Berntsen, Secretary for Home Affairs.
Thomas Larsen, Secretary for Public Works.
H. C. Steffensen, Chairman of the Upper House.
A. Thomson, Chairman of the Lower House.
V. Oldenburg, Mayor of Copenhagen.

President of the Congress:

Alex. Foss, Civil-Engineer and Manufacturer, Partner in the firm of F. L. Smidth & Co., President of the Association of Danish Masters of the Iron Industry, Copenhagen.

Reception Committee:

Ch. Ambt, Generaldirektör for de danske Statsbaner.

H. N. Andersen, Etatsraad, Direktör for Östasiatisk Kompagni.

Axel Berg, Architekt, Formand for „Akademisk Architektforening".

D. Berg, Direktör for Aalborg Portland-Cement Fabrik.

S. C. W. Bindesböll, Direktör for Helsingörs Jernskibs- og Maskinbyggeri.

O. Busse, Direktör for de danske Statsbaners Maskinafdeling.

Fr. Christensen, Professor, Indehaver af V. Steins kemiske Laboratorium.

R. Christiani, Ingen., Medindehaver af Firmaet Christiani & Nielsen.

C. M. T. Cold, Kaptajn, Direktör for Det forenede Dampskibsselskab.

C. E. Dahl, Kaptajn, Departementschef i Krigsministeriet.

F. Dalgas, Direktör for den kgl. Porcellænsfabrik.

C. F. Drechsel, Kommandör, Havnekaptajn i København.

S. A. Faber, Direktor for Skovshoved Elektricitetsværk.

Alex Foss, Ingeniör og Maskinfabrikant, Medindehaver af Firmaet F. L. Smidth & Co., Formand for „Foreningen af Fabrikanter i Jernindustrien i Köbenhavn" og for „Jernindustriens Sammenslutning".

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Thorne, A., Verksejer, Hönefos.

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Austria.

K. u. k. Reichs-Kriegsministerium:

Kodolitsch, Rich. Edler von, k. u. k. Major.

Metz, Karl, k. u. k. Hauptmann.

Ceipek, Const. Edler von, k. u. k. Hauptmann.

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Zweig, Heinrich, k. u. k. Oberster Schiffbauingenieur.

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Banús y Comas, Carlos, Colonel du Génie, Directeur du „Laboratorio del Material de Ingenieros".

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Metz, Karl, k. u. k. Hauptmann.

Ceipek, Const. Edler von, k. u. k. Hauptmann.

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Zweig, Heinrich, k. u. k. Oberster Schiffbauingenieur.

Stejnar, Franz, k. u. k. Oberstleutnant, k. u. k. Marine-, Land- und Wasserbaudirektor.

Königl. Ungarisches Landwehrministerium:

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Königl. Technische Hochschule, Budapest:

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Faller, Carl, ord. ö. Professor und königl. ung. Ober-Bergrat.

Königl. Hauptstädtischer Baurat:

Salkovits, Charles de, Ingénieur en Chef du Conseil supérieur des Travaux publics métropolitains.

Königl. Haupt- und Residenzstadt Budapest:

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Boehm, August, Ingenieur.

Königl. Ungarische Staatseisenbahnen:

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Riedl, Karl, Oberinspektor.
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United States Government:

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National Association of Cement Users:

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American Society of Mechanical Engineers:

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» Ingeniör Carlsen, København.
» Professor Christensen, Kbhvn.
» Landbrugskd. Christensen, København.
» Direktör K. Christensen, Aalborg.
» Ingeniör Christiani, Hamburg.
» Ingeniör Davidsen, Hellerup.
» Ing. van Elzelingen, Hellerup.
Frk. van Elzelingen, Hellerup.
Fru Ingeniör Engelhart, Hellerup.
» Direktör Faber, Hellerup.
» Ingeniör Alex. Foss, Valby.
Frk. Guimarais, København.
Fru Direktör Hagemann, København.
» Grosserer Halberstadt, Kbhvn.
» Professor Hannover, København.
» Bygningsinspektör Heinr. Hansen, København.
» Konsul Heineken, København.
Frk. Heineken, København.
Fru Direktör V. Helper, København.
Fru Baneingeniör Hiort-Lorenzen, Struer.
» Direktör H. C. Holm, København.
» Driftsbestyrer Holten Andersen, Uttrupgaard pr. Nörresundby.
» Ingeniör Hummel, København.
Frk. Hummel, København.
Fru Stadsingeniör Höeg, Aalborg.
» Ingeniör Jarl, København.
» Ingeniör Jensen, København.
» Telefondirekt. Johannsen, Kbhvn.
» Oberstlöjtnant C. Juul, København.
» Afdelingsingeniör Karsten, Kbhvn.
» Direktör Krog, København.
» Ingeniör Kähler, København.
» Ingeniör Poul Larsen, Kbhvn.
Frk. Paula Larsen, København.
» Johanne Larsen, København.
Fru Ingeniör Lorenz, København.
» Ingeniör Lundbye, København.
» Stadsingeniör Lundbye, Korsör.
» Entreprenör G. Lutz-Petersen, København.
Frk. Mangor.
Fru Borgmester Marstrand, Kbhvn.
» Telegrafdirektör Meyer, København.
» Laboratorieforstander Meyer, København.
Frk. Michaelsen, København.
» Mogensen, København.
Fru Ingeniör Monberg, København.
» Ingeniör Münter, Vassingeröd.

Fru Ingeniörkaptajn Möhl, København
» Ingeniör Möller, Hellerup.
» Direktör Möller, Hobro.
» Munck.
» Havnebygmester Möller, Kbhvn.
» Ingeniör Neergaard, København.
» Ingeniör Nyeboe, Charlottenlund.
» Oehlenschläger.
» Stenhuggermester L. F. Olsen, København.
» Ingeniör Pedersen, København.
» Ingeniörkaptajn Petersen, Kbhvn.
Frk. Valborg Petersen, København.
Fru Driftsbestyrer Petersen, Lemvig.
Frk. Ellen Petersen, Lemvig.
Fru Ingeniör Raaschou, København.
» Raaben.
Frk. Ramsing, København.
Fru Ingeniörkaptajn Reck, Hellerup.
» Ingeniör Riisager, København.
» Ingeniör Rump, København.
» Professor Rung, Hellerup.
» Ingeniör J. Saabye, København.
Frk. Saabye.
Frk. Saabye.
Fru Ingeniör Sardemann, Aarhus.
» Sporvejsdirektör Schmidt, Aarhus.
» Ingeniör Schöller, København.
» Smedemester Seifert, København.
» cand. polyt. Simonsen, Kbhvn.
» Ingeniör Smidth, København.
Frk. Karen Smidth, København.
Fru Ing. Sonne.
» Professor Steenberg, København.
» Ingeniör Steenstrup, Aalborg.
» Ingeniör Stenbjörn, Holte.
» Docent Suenson, København.
» Direktör Svanholm, København.
» Arkitekt Tvede, København.
» Stadsingeniör Voigt, København.
» Ingeniör Werner, København.
» Direktör Westergaard, Kbhvn.
» Belysningsdir. Windfeld-Hansen, København.
» Direktör Winslöw, Kobenhavn.
Frk. Clara Wolff, Aalborg.
Fru Stadsarkitekt Wright, København.
» Vanddirektör Öllgaard, Kbhvn.

Germany.

Frau Dr. Bruhn, Charlottenburg.
» Dr. Rud. Dyckerhoff, Biebrich a. Rh.
» Dr. Aug. Dyckerhoff, Biebrich a. Rh.
» Professor Eichhoff, Berlin, Charlottenburg.
» Dr. Framm, Karlshorst b. Berlin.
» Geheimer Ober-Baurat W. Germelmann, Berlin.
» Dr. Franz Hochstetter, Berlin.
» Geheimer Baurat J. Homilius, Dresden.
» Regierungs- und Baurat Labes, Berlin.
Frau Fabrikant Otto Leube, Ulm a. d. Donau.
» Regierungs - Baumeister G. Linde, Berlin.
» Professor M. Möller, Braunschweig.
Frl. Wilhelmine Möller, Braunschweig.
Frau Dr. Müller, Kalkberge (Mark).
» Dr. Paul Prüssing, Schönebeck a. d. Elbe.
» Ing. Schneider, Groß-Lichterfelde.
Frl. P. Siber, Stettin-Bredow.
Frau Dr. Tannhäuser, Berlin.
» Baurat Wendemuth, Hamburg.
» Baurat Weyrich, Hamburg.

France.

Mme. Bonet, Lille.
» Breuil, Paris.
» Cellerier, Paris.
» G. Charpy, Montluçon (Allier).
» Chaumonot, Mont-St-Jean (Côte-d'Or).
» Feret, Boulogne-sur-mer (Pas-de-Calais).
» Veuve Fontaine, Paris.
» Huillier, Paris.
Mme. Kammerer, Mulhouse.
» Leduc, Gagny (Seine-et-Oise).
» Lonquéty, Paris.
» Maurial, Paris.
Mlle. Maurial, Paris.
Mme. Rabut, Paris.
Mlle. Rabut, Paris.
Mme. Saladin, Paris.
» Simonot, Cherbourg.

Great Britain.

Mrs. Gulliver, Edinburgh.
» Hethey, Salisbury House, London Wall, E. C.
» Kirkaldy, London, S. E.
Miss Randall, Summer Court, Shooter's Hill, Kent.
Mrs. Rapelli, London.
» Rees, Swansea.
» Sachs, London, S. W.
» Sharrock, West Thurrock.
» Smith, Ealing.

Italy.

Mme. Fred. Giolitti, Triest.
« Emma Revere, Milan.
» Lina Scifoni, Rome.
Mme. la comtessa Marina Nicolis de Robillant, Turin.

Netherlands.

Frau A. Bienfait-Gallé, Amsterdam.
Frl. A. P. Burgdorffer, Rotterdam.
Frau Inckel Quispel, Haag.
» E. J. L. F. Raaymaakers van der Noordaa, Ede.
Frau B. E. Rutgers-Mees, Rotterdam.
Frl. van Hooru-Jonssen.
Frau A. M. v. d. Steen v. Ommeren-Hallo, Haag.

Norway.

Fru Kemiker Joh. Gram, Kristiania.
» Murermester Ernst Hanssen, Bergen.
Frk. Thekla Hiorth, Kristiania.
Fru Disponent H. Musculus, Kristiania.
Fru Kemiker Simonsen, Kristiania.
» Bygmester Thorstensen, Skien.
» Ingeniör Thorwald Wetlesen, Kristiania.

Austria.

Frau Marie von Arlt, Wien.
» Ober-Baurat Fritz Edler von Emperger, Wien.
Frl. Elga von Emperger, Wien.
Frau Gem.-Rat Fleischhacker, Brünn.
» Oberbaurat Karl Haberkalt, Wien.
Frl. Hermine Hanisch, Wien.
» Adele Hönigsberg, Wien.
» Dr. Clara Hönigsberg, Wien.
Frau Bauingenieur C. Lumir Kapsa, Pilsen.
Frau Ingen. Arthur Ritt. v. Kink, Wien.
» Major R. Edl. v. Kodolitsch, Wien.
» Prof. Bernhard Kirsch, Wien.
» Ingenieur Kluge, Prag.
» Ministerialrat Karl Marek, Wien.
» Hofrat Josef Melan, Prag.
» Bauingenieur Ant. Müller, Pilsen.
» Ingenieur Enrico Panfilli, Triest.
» Prof. Leopold Pfeffer, Kopenhagen.
» Minna Stiger, Wien.
» Malvine Wechsler, Wien.

Russia.

Mme. A Czarnomska, St.-Pétersbourg.
» M. Drouginine, St.-Pétersbourg.
» la princesse M. Gagarine, St.-Pétersbourg.
Mlle. la princesse S. Gagarine, St.-Pétersbourg.
Mme. A. v. Loesch, St.-Sonda.
» C. Nekrassoff, St.-Pétersbourg.
» la comtesse S. de Suzor, St.-Pétersbourg.
Mme. Nowgorodsky, St.-Pétersbourg.
» A. Tanenbaum, St-Pétersbourg.
» A. Tschernoff, St.-Pétersbourg.
» V. Welikhoff, Moscou.
» Zigler, Varsovie.
» S. Zwolinsky, St.-Pétersbourg.
Mlle. S. Zwolinsky, St.-Pétersbourg.
» S. Zwolinsky, St.-Pétersbourg.
» H. Zwolinsky, St.-Pétersbourg.
» V. Zwolinsky, St.-Pétersbourg.

(Finland).

Fröken Sigrid Engström, Helsingfors.

Fröken Mary Orrman, Helsingfors.

Sweden.

Fru Ingeniör A. Björkman, Stockholm.
» Ingeniör Johansson, Sandviken.
» Öfverstelöjtnant Lindahl, Stockholm.
» Byråingeniör Linton, Stockholm.
» Ingeniör de Skarengrad, Lomma.

Fru G. Scholander-Lundén, Billesholm.
» Öfvering. Svedberg, Billesholms Grufva.
» Direktör Wahlberg, Fagersta.

Switzerland.

Frau Dr. Amsler, Schaffhausen,
» Direktor Frey, Luterbach.

Frau Maillart, Zürich.

Spain.

Mme. Carlos Banús, Madrid.
» de Gálvez-Canero, Madrid.

Mme. de Zafra, Madrid.
Mlle. de Zafra, Madrid.

Hungary.

Frau Zentralinspektor Nicolaus Bálint, Resiczabánya.
» Oberingenieur J. Bartel, Budapest.
» Oberingenieur Max Bermann, Budapest.
» Direktor Moriz Breuer, Budapest.
» Betriebsleiter Joachim Jachzel, Tataros.
» Oberingenieur Franz Just, Györ.
» Ing. Edmund Kelényi, Budapest.

Frau Oberingenieur Kreiker, Szeged.
» Ingenieur Langfelder, Budapest.
» Direktor Löwenstein, Budapest.
» Ingenieur Maróthy, Budapest.
» Ing. Maximilian Moskovits, Nagyvárad.
» Hofrat Rejtő, Budapest.
» Oberingenieur Szívós, Budapest.
» Professor Zielinski Szilárd, Budapest.

United States of America.

Mrs. Dudley, Altoona.
» Tinius Olsen, Philadelphia.
» Henrik Bertelsen, Copenhagen.

Miss Anniet Pugh, Altoona.
Mrs. Talbot, Urbana.

First General Meeting, Tuesday September 7th.

Held in the Reading Room of the Royal University.

Meeting opened at 10 a. m.

The King and Royal Family assisted at the opening meeting. The following Honorary Members of Congress were also present:

H. E. the Minister President of Council Count Holstein-Ledreborg,

H. E. the Home Secretary Klaus Berntsen,

H. E. the Minister of National Defence J. C. Christensen,

H. E. the Secretary of State for Foreign Affairs Count C. W. Ahlefeldt-Laurvingen,

H. E. the Minister of Public Works

the Town Chief-President Mr. Oldenburg,

Government Representatives and other Delegates and Congress Members, who occupied every available space. The gallery was also occupied by a great number of distinguished guests. The Association of Students of the Academy gave a cantata composed and set to music for the occasion by Mr. Brógh which formed a most fitting opening to the sitting.

The President of the Association, Mr. Foss, took his stand on the platform and asked His Royal Highness Crown Prince Christian, as Honorary President of the Congress, to kindly address the Meeting.

His Royal Highness Prince Christian said:

"The importance of material testing is, one may say, "universally recognised. Governments have taken in hand "the controlling of materials in order to secure their good "quality. The fact that methods of testing are dealt with "by an International Congress affords a fresh proof of "the solidarity which exists among nations, which thus "attach value to working in agreement in this field as in "many others to the interests of peace.

"The very large number of representatives present at "this Congress forms a significant evidence of this fact; "its reality is sufficiently shown by the large gathering of "prominent members from all countries whom we see "here to-day.

"In the name of my countrymen I beg you welcome "and I express the wish that the results of the proceedings "upon the questions on the programme may be most "completely satisfactory.

"With the expression of this wish, and speaking in "the name of His Majesty the King, Patron of the Fifth "International Congress for the Testing of Materials, I "declare this Congress open." (Enthusiastic applause.)

Mr. Foss, the President of the Congress, then made the following speech:

Your Majesties!
Your Royal Highnesses!
Gentlemen!

In the name of the International Association for Testing Materials, and more especially in that of the members of the present Congress, I beg leave to tender to Your Majesty our deepest thanks for the very high honour which has been conferred upon us by Your Majesty gracefully accepting to act as Patron of the Congress and to be present at the opening session.

The aim which our Association has in view, the international unification of the methods of testing materials of all classes, and the problems which are before us, are of the greatest importance in regard to engineering and the advancement of technical knowledge, and it is hoped they will be brought much nearer to a solution by the work of the present Congress. Since, however, they have not received general publicity, the graceful interest which has been shown by Your Majesty to the work of this Congress is of immense value to our Association, and one of its effects will be to greatly facilitate our task, inasmuch as it will direct public attention to our efforts.

The engineers who are here gathered from all parts of the world beg therefore to thank Your Majesty for the interest which

Your Majesty has been graciously pleased to show in the work which lies before us.

Gentlemen, let us express our thanks by giving three cheers to His Majesty, the King of Denmark. Long live His Majesty King Frederik! *(The whole assembly responded with enthusiasm.)*

In the name of the Association I beg to thank Her Majesty the Queen and the Royal Family for their presence. I thank also Your Royal Highness for having consented to be the Honorary President of the Congress and for the welcome which Your Royal Highness has kindly extended in such graceful terms to the members of the Congress present.

I thank our Honorary Members, the Secretary of State for Foreign Affairs, the Home Secretary, the Minister of Public Works and the Minister for National Defence, for the support they have been pleased to give us; the Presidents of both Houses of Parliament for their kind aid; the Town Chief-President for the very great services afforded us by the Town of Copenhagen. Had it not been for the kindness which it has received from all these Authorities, the Organising Committee would have been unable to fulfil the necessary preparatory work for holding the Congress.

In the name of the Association I welcome the very numerous Government delegates and express the hope that you, Gentlemen, will take home with you a favourable impression of the way in which we deal with the important problems which lay before us, with the result that Governments will afford to us in a larger measure than in the past their aid towards the attainment of our aims.

In the name of the Council I now turn to the Members of the Association and am thankful for the large number of delegates present, representatives of numerous corporate institutions and individual members who work in conjunction with our Association.

The presence of approximately nine hundred members, seven hundred of whom have come from abroad, a much larger attendance than that of the former, already largely attended, Congresses, affords a most pleasing sign for the further development of our activity.

I welcome specially the goodly attendance of British Delegates; the coming together of the Continental European nations with the English speaking world to take in hand and to decide in common

the problems before us, forms one of the most important features of this Congress.

Since the most satisfactory fourth Congress which took place in Brussels in 1906, the International Association for the Testing of Materials, far from having remained at a standstill, has greatly developed.

Scientists and Engineers of all nations have eagerly dealt with the subjects on our programme, and the lively exchange of views and of experimental results which is greatly encouraged by our Association has had for effect to greatly stimulate further research work. This has increased the activity of the existing national institutions and has led to the formation of other new and important institutions in Italy, Austria and Russia.

In no way has this decreased the weight that attaches to the International Association as a body, on the contrary, the importance of the unification of testing methods and testing conditions is becoming more and more generally recognised.

An excellent proof of the energy which is being displayed in every land for solving the questions before the Association is afforded by the large number of reports dealing with most important questions in material testing and which have already been handed in for consideration at the meetings of the present Congress.

The International Committees appointed by the Association for solving several of the problems which are before us have continued their work for the past three years. The reports sent to the Congress by the committees referred to show that a number of questions have been brought nearer to a solution: in some of these are to be found recommendations the acceptance of which by the Congress will, without doubt, have important results. In this connection I may mention the work of Committee I, on International specifications for iron and steel.

With regard to the work of the Council, this is set forth in a printed report and I shall not enter into it in detail. I should like to mention, however, the starting by our Association of a journal in three languages; this will not only greatly contribute to unite the members together, but will form an international medium of high scientific and technical value.

The increased activity on the part of the Association and in a large measure also the publication of this journal, will have for

effect to cause greater demands to be made upon the funds of the Association. We shall not be able to meet these demands with the present very moderate annual contribution notwithstanding the increase in Membership, and the Council therefore decided yesterday to raise this from 7.50 Frcs. to 10 Frcs. annually.

The work of our Congress is distributed over three sections and I have now the pleasure of naming the following Honorary officers.

Honorary Secretaries of the General Meeting.

Mr. Brignon, Colonel, Directeur des Ateliers de l'Artillerie à Puteaux.

Mr. P. D. C. Kley, Professor of the Technical College, Delft.

Mr. G. C. Lloyd, Seretary of the Iron and Steel Institute, London.

Mr. A. Greil, Baurat, Leiter der städtischen Versuchsanstalt, in Wien.

Honorary Presidents.

Section A (Metals).

Austria: His Excellency Geheimrat, Sektionschef Dr. *Wilhelm Exner,* Vienna.

Belgium: *Léon Thirionet,* Chief Engineer, Director of the Belgian State Railways, Brussels.

Denmark: *G. A. Hagemann,* Director of the Technical High School, Copenhagen.

France: *H. Le Chatelier,* Inspecteur Général des Mines, Membre de l'Académie des Sciences, de l'Institut de France, Paris.

Germany: Wirkl. Geheimer Oberbaurat Dr. *H. Zimmermann,* Berlin.

Great Britain: *J. E. Stead,* F. R. S., London.

Holland: *J. Schroeder van der Kolk,* Govt. Engineer, the Hague.

Hungary: *Geduly Gyula,* Ministerialrat, Director of the Royal Hungarian State Railways, Budapest.

Italy: *St. Fadda,* Ingénieur-Directeur, Rome.

Norway: *I. E. Gunstensen,* Director, d. Technischen Lehranstalt, Trondhjem.

Russia: His Excellency *D. Tschernoff,* Professor, St. Petersburg.

Sweden: Chief Engineer *I. Brinell,* Stockholm.

Switzerland: *Julius Weber,* President of the Swiss Locomotive Works, Winterthur.

United States of America: *Wm. R. Webster,* Consulting Engineer, Philadelphia.

Honorary Presidents.

Section B (Stone, Cements, etc.).

Austria: Sektionschef, Dr. *Franz Berger,* Vienna.

Belgium: *Van Wolsom,* Engineer, Brussels.

Denmark: *H. C. V. Möller,* Harbour Chief-Constructor, Copenhagen.

France: *R. Feret,* Directeur du Laboratoire des P. E. C., Boulogne-sur-mer.

Germany: Geheimer Oberbaurat *W. Germelmann,* Berlin.

Great Britain: *Edwin O. Sachs,* F. R. S., London.

Holland: *M. Haaymakers,* Captain of the Corps of Engineers, the Hague.

Hungary: Hofrat, Professor *Desider von Nagy,* Budapest.

Italy: *Claudio Segré,* Director of the State Railways, Rome.

Norway: Professor *J. H. L. Vogt,* Christiania.

Russia: *W. Czarnomsky,* Ingénieur Conseiller d'Etat, St. Petersburg.

Sweden: *P. Axel Lindhal,* Senior Lieutenant, Stockholm.

Switzerland: Director *Haas,* President of the Swiss Association of Cement Manufacturers, Dittingen.

United States of America: *Rich. L. Humphrey,* Consulting Engineer, Philadelphia.

Honorary Presidents.

Section C (Various Materials).

Austria: *Heinrich Zweig,* Chief Government Naval Architect, Vienna.

Belgium: *E. Camerman,* Chief of the Testing Department, Belgian State Railways, Brussels.

Denmark: Prof. *N. G. Steenberg,* Copenhagen.

France: *F. Cellerier,* Directeur du Laboratoire d'Essais du Conservatoire National des Arts et Métiers, Paris.

Germany: Wirkl. Geheimer Oberbaurat *Veith,* Berlin.

Great Britain: *J. T. Milton,* Delegate of Lloyd's Register of British and Foreign Shipping, London.

Holland: *A. J. M. Stoffels,* Government Director of Construction, the Hague.

Hungary: *A. Grittner,* Inspector of the Royal Hungarian State Railways, Budapest.

Norway: *E. Simonsen,* Chemical Expert, Christiania.

Russia: Prof. *A. Kroupsky,* St. Petersburg.

Sweden: Chief Engineer *I. Brinell,* Stockholm.

Switzerland: *Keller,* Chief Engineer Swiss Federal Railways, Bern.

United States of America: *W. K. Hatt,* Civil Engineer, Professor, Lafayette, Ind.

Honorary Secretaries.

Section A (M.tals).

Belgium: *A. Galopin,* Sub-manager of the National Small Arms Factory, Liège.

Germany: Prof. Dr. *E. Meyer,* Techn. High School, Charlottenburg.

Great Britain: Dr. *Walter Rosenhain,* National Physic. Laboratory, Teddington.

Holland: *P. Maas Geesteranus*, Chief Engineer Dutch Railway Co., Amsterdam.

Hungary: Dr. *W. Misángyi,* Engineer, Budapest.

Italy: *F. Giolitti,* Dr., Prof., University, Turin.

Norway: *Chr. Storm,* Engineer, Trondhjem.

Russia: His Excell. *Klemm,* Governor Councillor, St. Petersburg.

Switzerland: Prof. Dr. *P. Weiß,* Federal Politechnikum, Zurich.

Honorary Secretaries.

Section B (Cements).

Belgium: *Em. Hiertz,* Chief of Blast Furnace Dept., Cockerill Works, Seraing.

Germany: Prof. *Max Möller,* Techn. High School, Brunswick.

Holland: *J. A. v. d. Kloes,* Professor, Techn. High School, Delft.

Hungary: Dr. *B. v. Brzesztovsky,* Lecturer Techn. High School, Budapest.

Italy: *G. Revere,* Professor, Milan.

Norway: *J. G. Lund,* Professor, Trondhjem.

Russia: Prof. *P. Welikhoff,* Engineer, Moscow.

Switzerland: *R. Frey,* Director Cement and Lime Works, Luterbach.

Honorary Secretaries.

Section C (Various Materials).

Belgium: *H. de Gorski,* Engineer, Private Secretary to the Director of the Cockerill Works, Seraing.

Germany: Prof. Dr. *Hinrichsen,* Groß-Lichterfelde.

Hungary: *Franz Just,* Chief Engineer, Hungarian State Railways, Győr.

Norway: *Joh. Gram,* Dr., Chemist, Norwegian State Railways, Christiania.

Russia: *A. Bormann,* Engineer, St. Petersburg.

Members of Council who open the Sections:

Section A: Geheimrat Prof. Dr. A. Martens, Gr.-Lichterfelde.
„ B: Prof. F. Schüle, Zurich.
„ C: Prof. A. Mesnager, Paris.

Honorary Treasurers:

Director A. Granfelt, Helsingfors.
Engineer L. Bienfait, Amsterdam.
Engineer S. A. Lund, Christiania.

The following Gentlemen are the Chairmen in charge of the Sections:

Section A: Director O. F. A. Busse, of the Danish State Railways, Copenhagen.

Section B: Captain T. Grut, Copenhagen.

Section C: Commander B. Münter, Copenhagen.

I beg these Gentlemen to kindly take up their office and so to assist their respective sections that the important transactions of the latter may lead to most complete results, notwithstanding the difficulty of carrying out the discussions in three languages. The organising committee has endeavoured to secure the best possible arrangements for the work of the different sections, in order that our Congress may fulfil its main object and be a working Congress.

Our achievements on this occasion will, so to speak, mark a jubilee, since the "foundation stone" of the Association was laid twenty-five years ago:

In September 1884 a number of independent gentlemen, passionately devoted to scientific questions, met together at the invitation of Bauschinger, in order to devise the best methods

for testing, and to unify the testing of materials. The first meeting took place in Munich exactly twenty-five years ago and the International Association for the Testing of Materials has sprung from this first meeting. It gives us very great pleasure to add that from among the seventy-nine scientists who were at the first meeting, standing so to speak at the cradle of the Association, we are now able to greet several who are present here to-day and who have accompanied the Association all the way, furthering its cause. These Gentlemen are our two Vice-Presidents, Geheimrat Martens and His Excellency Prof. Belelubsky, His Excellency Prof. Exner and Dr. Engineer R. Dyckerhoff.

Several of the problems which were brought up in 1884 are still occupying the attention of the Association. At that early date, Prof. Exner had already placed prominently on the programme of questions to be dealt with the subject of microscopical investigations into the components of metals, which has since acquired such a great importance. We see also in our past president, Mr. Berger, one of the first contributors to the problems of stone and mortar tests.

Our Congresses differ from most other International Congresses in that they deal with points of international agreement which, although not issued in the authoritative terms which are used in all questions of law, are gladly followed by the technical world and by us, engineers, who have been brought up in submission to the Natural Laws.

Such agreements are not easy to arrive at and should not be decided upon in a hurry. They necessarily encounter many difficulties in their application owing to the variety in practical methods and industrial interests in the different countries. Where complete agreement has been reached, a very satisfactory state of matters has been the result. At the present time, when so large economical and national interests are involved, nothing is more important than arriving at an understanding in regard to technical questions.

The beneficial results which are achieved by our Association and our Congresses are felt far beyond the sphere of the technical world; they influence the home life of nations; they make for concord by establishing peaceful and friendly intercourse on weighty interests of an economical nature. We work therefore at

one and the same time for progress in technics and for the peace of the world.

It is our hope that the Fifth Congress will add a valuable contribution to this noble object. (Enthousiastic applause.)

Mr. **Poul Larsen** then read the following report on the Development of the Danish Cement Industry:

The Development of the Danish Cement Industry.

On account of her natural climatic and geological conditions, Denmark has in the past and will in the future, in a large measure depend upon agriculture as her principal trade occupying a very large part of the population. The industrial development of Denmark will naturally, therefore, lie in the direction of refining the agricultural products, as the Danish soil only offers a small foundation for the development of a mining industry in the absence of accessible minerals of any commercial value. Limestone is one of the few exceptions to this rule, as lime form the immediate sub-soil of Denmark and is in many places accessible at varying depths, in some cases as a formation of chalk outcropping at the surface, as for instance in the northern part of Jutland, in other cases in deeper lying strata covered by the deposits of the glacial period. It is on the occurence of the chalk, in a condition suitable for technical purposes, that the Portland cement industry of Denmark is based.

This industry, which has now reached a high degree of perfection has mainly been built up during the last 20 years, often under most difficult conditions, and without any support whatever from the State in the shape of a protective duty, or in any other way, but constantly contending against the strong competition from surrounding countries, most of which are protected by high tariffs, and which formerly provided Denmark with the largest part of the cement which it consumed.

The following figures will illustrate the development during the past 20 years:

In the year 1889 the total production in Denmark was 115.000 barrels Portland cement; the importation being 135.000 barrels.

In the year 1908 the total production was 1,560.000 barrels, of which 1,110.000 barrels were sold in Denmark and 410.000 barrels were exported, whereas the importation had decreased to less than 100.000 barrels.

The present capacity of the Danish cement factories is, however, 2,600.000 barrels, or more than twice the consumption of the country.

A drawback for the success of the cement trade lies in the circumstance that the country is absolutely devoid of water power and coal, wherefore the fuel, which is so important a factor for this trade, must be imported from abroad; but here the cement manufacturer met with the extraordinary difficulty that the State imposed an import duty on coal and thus made this very important raw material still more expensive. Similar conditions have prevailed in respect of material for packing, such as staves for casks, iron hoops and bags, on which articles a proportionately high import duty was levied by the State, whereas on the other hand the foreign cement, inclusive of its packing, has always been imported free of duty into Denmark. It is, therefore, a fact that the Danish State has handicapped the Danish cement industry to the advantage of the foreign manufacturers, and it was not until the 1st of January this year that the effect of this absurdity was diminished by the passing of the new Danish tariff. On the other hand most of the countries to which Portland cement could be exported from Denmark on account of the natural geographical conditions have protected their industries by high tariffs. This is the case for instance in Norway, Sweden, Russia, France, Spain, the United States of America, and Canada, etc., whereas only England, Germany, Belgium and Holland have no duty on cement. The conditions have then been most unfavourable for Denmark in these respects, and it is in view of these facts that the development of the Danish cement industry must be considered.

In spite of these difficulties the Danish cement industry has now reached a standpoint from which it is able to cope with the industries of the surrounding countries. This is mainly due to the advanced state of its technical development, which is obtained to a large extent by the constant introduction of new and original inventions.

A report on Danish cement manufacture will then naturally to a large extent be a report on Danish technical improvements; but the country and its trade are too small to show the value of these improvements with sufficient clearness. Only in demonstrating the influence which these improvements have had on the development of the industry in the larger countries will it be possible to throw sufficient light on the question.

The Portland cement industry of Denmark originated in 1868 when the small factory "Hertha" on Seeland was built. This factory as well as the second works "Rödvig", also on Seeland, never attained any prominence. Both factories stopped about 20 years ago.

The seven factories now existing are all situated in the northern part of Jutland at the Limfjord and the Mariagerfjord. These works came in existence in the following order: "Cimbria", in 1873, "Dania", in 1887, both at Mariagerfjord, "Aalborg Portland Cement Works", in 1889, "Danmark", in 1898, "Norden", in 1901, "Nörresundby", in 1907, all lying at the Limfjord, and "Kongsdal", in 1908, at Mariagerfjord.

The earlier works including "Cimbria" and "Dania" were all operated on the "thin slurry process", which was generally used for many years in the cement producing countries of northern Europe. The raw materials were dissolved and mixed in wash mills with a large proportion of water, and the slurry was run into open basins, where it was left for a very long time until the solid part of the slurry had precipitated, whereupon the surplus of water was drained off. The slurry was afterwards dug out of the basins in a soft state, formed into bricks and dried in open sheds or in tunnel dryers, before the burning could take place. This whole process was very troublesome, required a considerable time and much labour, and limited the operation of large parts of the factories to a single season.

This "thin slurry process" has been improved to some extent, especially in England through the introduction of the Chamber kiln, in which the slurry is dried out artificially by the waste heat from the shaft kilns. A more continual operation is obtained thereby, the labour is somewhat reduced, but the manufacturer is forced to use the expensive coke as fuel and cannot avail himself of modern fuel saving kilns.

Notwithstanding these difficulties the "thin slurry process" has been adhered to in many places up till recent years, and the Chamber kilns are still in existence in England, although they are now largely being abandoned.

With the building of the "Aalborg Portland Cement Works" the Danish cement industry entered quite original paths. The problem of making Portland cement out of soft, moist raw materials, on a continuous process independent of climatic and atmospheric disturbances was solved by introducing the "Dry process".

Instead of dissolving chalk and clay together in water, these materials were dried separately in two large drying towers of special design, large enough to enable the total quantity of the respective materials to pass through them. — Afterwards the raw materials were mixed and ground together in a dry state. The introduction of the "dry process" at "Aalborg" gave very good results, and a considerable saving of cost in the manufacture as compared with the "thin slurry process" was therefore effected.

About the year 1890 the old discontinuous shaft kiln formerly in use everywhere on the continent had been abandoned, and the so-named Dietzsch kiln was generally adopted. The Dietzsch kiln worked continuously, but had a rather small capacity and required a considerable amount of labour in attendance. In designing the "Aalborg Portland Cement Works" a new type of kiln was adopted, the so-called "Aalborg" kiln, which originated from Germany and was invented by Mr. Schoefer in Itzehoe. The kiln was, however, in its early form quite unusable, and it, therefore, never attained any success in Germany. After unsuccessful trials at "Aalborg" the kiln was completely rebuilt and proved in its new form to be a complete success. The kilns have been in constant operation at "Aalborg Portland Cement Works" from 1891 until the beginning of 1909, i. e. during 18 years, and have been working with a coal consumption of only 13 per cent., a result hardly obtained in any other continuous shaft kiln.

The adoption of this kiln had the great advantage that all the cement burning could be accomplished by the use of coal alone, thus rendering the expensive coke production unnecessary.

The "Aalborg" kiln has since undergone several modifications, one form of which, named the "R" kiln, demands attention on account of its very large capacity. In some of the American

cement works the "Aalborg" kiln has been provided with suction draught, whereby its capacity has been largely increased. After the success which was obtained in the "Aalborg Portland Cement Works" with this kiln it has been adopted to a large extent in the foreign cement industry. More than 90 kilns have been built in all European countries, the United States of America, Canada and China, corresponding to an annual output of more than 3,000.000 barrels.

In using the dry process, it is always necessary to add a certain amount of water to the dried raw material in order to form it into bricks. Only in this form is it possible to treat the raw materials in the shaft kilns. The water added must, however, be evaporated again before the burning, and this means, therefore to some extent a loss in manufacture. This circumstance was utilized in the first extension of the "Aalborg" factory to obtain a larger production in a very cheap way by introducing a combined wet and dry method. Wash mill practice had attained a high degree of perfection in the clay brick manufacture in Denmark, where the clay is often very impure, and the experience gained in this industry was now utilized in cement manufacturing by the production of a chalk and clay slurry of very thick consistency. This thick slurry was mixed together with the raw meal from the old factory working on the dry method. In this way a stiff plastic mass was obtained which could be made into ordinary wirecut bricks, and which furthermore gave a much stronger brick than it had formerly been possible to obtain by pressing the dry raw meal alone. The introduction of this combined wet and dry method eliminated all the drawbacks of the thin slurry method and the dry process, and retained their advantages and after the introduction of this combined method the "Aalborg" kiln yielded, on account of the stronger bricks, a much larger output than formerly. Moreover this method paved the way at the "Aalborg Portland Cement Works" for the introduction later on of the thick slurry method now generally adopted, and used in connection with burning in rotary kilns.

At the same time as the treatment of the raw materials and the burning of these developed on the lines just mentioned, the grinding of the cement clinker underwent an epoch-making change.

Up to the year of 1892 the grinding of the cement clinker was generally effected in machines adapted from flour milling methods.

The continuous ball mill, which originated in Germany, where it was termed „Kugelfallmühle“, formed an exception. This machine was, however, not well adapted for fine grinding of cement, as the fineness was obtained in sifting the cement, and this operation could not be performed with advantage together with the grinding in one operation. As the requirements for fine grinding were raised, the insufficiency of all the existing machines for fine grinding became more apparent.

At this time the Danish civil engineer, F. L. Smidth, had invented the so-called Sand Cement, a mixture of sand and cement ground together to an impalpable powder, which in spite of its large content of sand showed quite remarkable strengths. All the machines then known were quite inefficient for making this product in an economical way, until a new machine was tried, which was invented and patented by the Danish civil engineer, Mr. M. Davidsen. This machine, which was called the Tube mill, was capable of grinding to any required fineness with the total elimination of all sieves. It therefore proved to be of great advantage not only for the manufacture of sand cement, but also for the grinding of Portland cement. Its grinding effect was so great that about 50 per cent. of the horse-power required was saved as compared with most grinding methods used formerly. It is now generally adopted throughout the entire cement industry of the world, and its name is used in characterizing a whole class of machines. The Tube mill is distinguished by its eminently simple design, its large capacity, steady running, small repairs, and the extreme fineness and uniformity of its product, and it has therefore had the greatest influence on the development of the Portland cement industry in all countries after having been introduced first in the Danish cement industry. Being at first adopted for the grinding of the burnt product, called cement clinker, its use has later on been extended to the grinding of raw materials and slurry, and also for the grinding of powdered coal for burning in rotary kilns, so that this machine is now used in its different forms in all the various departments of the cement factory. Its value is possibly best demonstrated when it is considered that now 1391 Tube mills of Danish origin are running in 108 factories in the United States

of America and Canada, in 328 factories in Europe and in 21 factories in India, China, Japan, Australia, South-Africa and South-America. The total horse-power required by these machines is about 75.000 and their annual output calculated on Portland cement clinker is about 30 million tons or 180 million barrels.

The Tube mill is only intended to perform fine grinding, which means the reduction of the material from a coarse to a fine powder. A preliminary treatment of the materiel to change this from fairly large pieces down to a coarse powder of uniform fineness is therefore necessary. To perform this work, a continuous machine, called the Kominuter or Kominor, has been invented by the Danish engineer, Mr. Poul Lindhard. This machine is in operation far superior to the ball mill mentioned before, more especially after having been provided with the new sifting system, called the Fasta sieves, invented by the Danish engineer, Mr. Fasting. The Kominor as well as the Tube mill has been largely adopted by the world's trade, and is now used to the number of 463 in 194 works in all the countries in Europe and America, and with an annual output corresponding to 13·5 million tons or 81 million barrels of cement.

It is only possible here to mention these main features of the improvements, on which the Danish cement industry has been built up, but in addition to these there are a great number of important original smaller machines and apparatus, which originated in the Danish cement factories, and later on have been introduced into the cement trade of the world.

During the year of 1898 there commenced at the "Aalborg Portland Cement Works" the radical change in the manufacturing methods which later on was followed in the cement industry of Europe, and which now gives this industry its feaiure, viz. the introduction of the rotary kiln.

The rotary kiln provided a means of burning the cement raw material in the shape of a powder or slurry, thus totally eliminating the manufacturing department where the raw material is made into the shape of bricks necessary for the burning in shaft kilns. Its introduction meant, therefore, a great simplification of the manufacture.

The rotary kiln for cement burning originated in England, but was there never carried beyond the trial state into practical

use. The principles of the rotary kiln are laid down in English patents for 1877 and earlier years. The trials which were made much later in Germany, have also been without any very great influence upon the development of rotary kiln practice.

It is beyond any doubt due to the Americans that the rotary kiln was brought into a form suitable for the cement industry. It is easy to understand why this new invention was met with so much more interest in America than in Europe, and why the Americans carried all the preliminary trials through with so much energy in spite of heavy expenses and failures. If the cement industry in the United States had been based on the methods developed in Europe this trade would have been heavily handicapped by the high price for labour in America and by the necessity of procuring in a short time a large staff of skilled, well-trained men; whereas on the other hand the question of fuel economy was a question of smaller consideration on account of the low prices for fuel in America. The rotary kiln thus promised to meet the American demand, as its successful introduction was to result in simplifying the manufacture, totally eliminating the labour-consuming brick department and very greatly reducing the labour in the kiln department.

The rotary kiln was introduced in America at the close of the 'eighties. Its practical value being proved, the rotary kiln gained rapidly in use in spite of its heavy fuel consumption, and it is without any doubt due to this kiln that the American cement industry has attained its present phenomenal extension.

From the introduction of the rotary kiln in America and up to the year of 1897 the fuel used for the rotary kiln was crude oil, which was obtainable at a reasonable price near the American oil districts, but which it would have been very difficult to use in most parts of Europe on account of its high price. However, about the year 1897 the price of crude oil in America was raised to such an extent that it was necessary to try to replace it by powdered coal, and as soon as this had been done successfully the rotary kiln was brought into a shape, which opened up the possibility of using it to advantage in Europe.

The rotary kiln practice in America had been closely followed in its development by the "Aalborg Portland Cement Works", and at the moment when coal dust firing had been successfully

tried the necessary steps were taken to introduce it in Denmark, and a contract was closed to this effect at the beginning of the year 1898.

Rotary kiln practice in America was, however, mainly based on burning cement manufactured on the dry method, as all the factories in the eastern part of America are mainly concentrated in the Lehigh valley in Pennsylvania, where the raw material consists of a dry argillaceous limestone. There were a few factories in Ohio working on the wet process because the raw material there consits of marl, a material containing a large amount of water, and which is moreover often dug below water. This material contains so much water that it is necessary to work it as a thin slurry with at least 50—60 per cent. of water, and as all this water had to be evaporated in the rotary kiln afterwards this process could not be very economical and could not at all have answered the purpose in Europe.

When the rotary kiln, therefore, was introduced at "Aalborg Portland Cement Works" it met here conditions different from those prevalent in America. In addition to the saving in labour which the rotary kiln could effect, it was equally important here to obtain the best possible economy in fuel.

For this reason the "thick slurry process" hitherto successfully carried on at "Aalborg Portland Cement Works" was also adopted for the new rotary kiln departement as providing the means for preparing the raw materials in the cheapest and most reliable way and with the least possible amount of water.

The "thick slurry process" in connection with rotary kilns has in the last 10 years been constantly improved and has now been adopted by the entire Danish cement industry. The new factories: "Norden", "Nörresundby" and "Kongsdal", are based on this process, and the other factories have abandoned their old way of manufacture and rebuilt their plants in accordance with this method.

The improvements introduced in the rotary kiln have resulted in a much better fuel economy and a much higher capacity than formerly obtained. The rotary kilns imported from America were 20 metres long with 1·8 metres diameter and yielded a daily output of about 150 barrels with a coal consumption of 55—40 per cent., whereas the modern Danish kilns are 50 metres long

and 2,7 metres in diameter, and yield an output of more than 600 barrels with a coal consumption of only about 25 per cent. The thick slurry process combined with fuel saving rotary kilns affords so great advantages in the manufacture, that this process is now largely adopted by foreign factories not only for moist and soft raw materials, but also to a large extent where dry raw materials are used.

As an illustration I might mention that a very large number of rotary kilns operated on this Danish practice are running at 63 cement works in all European countries with an annual capacity of about 14 million barrels.

The present standpoint of the trade, compared with the conditions prevailing 15 years ago, may briefly be described by stating the following facts:

The manual labour necessary within the factories themselves has been reduced to about one sixth of what it was formerly. Where in the year 1897, 1200 men were required for producing the cement now utilised in Denmark, 200 men are now able to do the work.

The total fuel consumption per barrel of cement produced is now no higher using the rotary kiln than it was when using the continuous shaft kiln in connection with Tunnel driers.

The first cost of plant has been reduced to less than half of what it was formerly.

It is not likely that future improvements will bring about any radical change or saving in the Danish thick slurry method for the reason that labour has already been reduced to a minimum and the sources through which a saving in fuel might still be obtained are very limited.

It may then justly be said that the Danish cement industry of to-day rests on a sound foundation. Its present capacity is about 2,600.000 barrels, or considerably more than twice the consumption of the country.

The balance of the production is sold for export, for which Denmark has favourable conditions on account of her geographical position. Export takes place to Sweden, Norway, Germany, Russia, Finland, England, South-America, South-Africa and East-Asia.

I have tried to point out the main steps in the evolution of a small industry in a small country, which grown up without any kind of protection, but in constant and lively intercourse with allied trades of foreign countries. Hereby it has attained its sound constitution. . We have learned by experience that nothing can be gained for a modern industry in hiding it behind artificial protective bars; its healthy development must rest mainly upon the pillars formed by technical science and art, and the international co-operation of men, that co-operation which is also the leading idea in the work of the present international association. (Enthousiastic applause.)

The Association of Students of the Academy then rendered a second cantata which most fittingly brought to a close the opening meeting of Congress.

Proceedings of Section A (Metals).

I. First Day of Meeting. Wednesday, September 8th, 1909.

Professor **A. Martens** opened the proceedings at 9—45 am. He invited the Chairman, Director O. Busse, as well as the honorary Presidents and honorary secretaires to take their seats on the platform.

Having taken the chair, Director O. **Busse** welcomed the many members in attendance and called upon Prof. Heyn to introduce the first subject to be discussed, "Metallography".

Metallography.

Prof. **E. Heyn** (Gr.-Lichterfelde near Berlin) gave a brief summary of his report (I_1) "On Progress made in Metallography from the Brussels Congress up to the Commencement of 1909." Metallographical research, he pointed out, had chiefly been concentrated upon the following objects:

a) To lay down the foundations for a Chemistry of Intermetallic Compounds by determining the cooling curves of as large a number as possible of alloys without regard to their practical utility. This was the chief aim of Prof. Tammann's work in Göttingen.

b) The further study of the system Iron-Carbon. The Formation of Graphite. The Constituents of Hardened Steel.

c) The further study of the Special Steels and other Alloys of direct technical utility.

d) The application of Metallography to an enquiry into metallurgical processes, especially those relating to metals other than iron. The Theory of the formation of matte and of speiss. This was the particular domain of the researches of Prof. Friedrich, of Freiberg.

e) Improvement of metallographical processes with special regard to the Testing of Materials. Especially to devise simple methods for ascertaining the previous treatment of metals and alloys (heat treatment, hardening and tempering, degree of cold-working and subsequent heating). This field had particularly been taken up by the Königl. Materialprüfungsamt at Gr.-Lichterfelde (Heyn and Bauer).

The speaker referred to the investigation which he had been conducting, in conjunction with Bauer, into the influence of the previous treatment of the steel upon its solubility in sulphuric acid: These researches promised to enable metallographers to draw conclusions as to the previous treatment of a steel from its solubility. The researches tended to shew that the transition from hardened steel (martensite) to annealed steel (pearlite) was not direct; there was a well-characterised, metastable intermediate modification. which had been termed „osmondite“ in honour of Osmond and which stood between troostite and sorbite. In tempering the martensite was first converted into troostite which at about 400^0 C. approached the osmondite stage; on further raising the temperature the osmondite passed into sorbite and finally into pearlite. Osmondite was characterised by a great solubility in diluted sulphuric acid and also by turning dark when etched with alcoholic hydrochloric acid of 1 per cent. Troostite, when dissolved in sulphuric acid of 10 per cent under exclusion of air, yielded gaseous hydrocarbons whose carbon contents was entered as C_h, and it further left a residue whose carbon was insoluble in concentrated hydrochloric acid and was designated C_f. This residue could not be carbide, since carbide was completely dissolved by hot, concentrated hydrochloric acid under evolution of hydrocarbons. The modification of carbon, found in troostite, must hence be different from carbide carbon. Carbide, dinstinguished by being insoluble in sulphuric acid of 10 per cent when air was excluded, but subsequently soluble in hot concentrated hydrochloric acid, was not noticed until a temperature of about 400^0 C. was reached in the osmondite stage, and increased rapidly afterwards with rising temperature. The contents in C_f, rose from martensite to osmondite, to decrease again afterwards.

In his memoir on “Experimental Researches on the Quenching Power of Liquids and on the nature of Austenite“ Benedicks

had come to very interesting conclusions. According to these researches austenite could not be preserved during quenching when the pressure was sufficiently large. For that reason austenite did not occur at the surface of hardened steels, but only in their interior.

Benedicks had mentioned one case, in which the originally present austenite had subsequently changed into martensite, when the outer skin of a quenched steel had been ground off and the pressure thus been released.

As to other features Prof. Heyn referred to his report which, in its table of all the metallographical papers published since 1906, afforded an illustration of the intense activity in this field; he also mentioned, with special regard to the work done in Germany, that the Königl. Materialprüfungsamt had itself since 1906, trained in metallography no fewer that 31 persons on the request of large establishments.

Dr. **C. Benedicks** (Upsala) congratulated the author on the concise clear language of his report and spoke in detail of his own Colloid-theory of troostite, as to which he differed from Prof. Heyn. This theory regarded troostite as a solid, colloidal solution or, better expressed, as a solid colloidal system of extremely small carbide particles, dispersed like impurities throughout the iron. Prof. Heyn did not know of any proof that this body X, whose existence was undoubtedly established by an evolution of heat, was really a carbide. A rigorous proof was indeed impossible; for the mechanical or chemical isolation of ultramicroscopical particles of iron carbide was out of question. It was characteristic, however, that well-identifiable carbide was so easily separated from the body X. Benedicks quoted a number of examples in which the existence of certain bodies had not been questioned, though a rigid proof could not be given. Ostwald had rightly stated that one could not strictly assert: "There is copper in this or that solution", but one could only say, that copper could easily be obtained from this solution. Something of that kind might be accepted for troostite. The speaker desired to accentuate that the colloid-theory did not at all contradict the fact established by Heyn and Bauer, that there was a metastable intermediate stage between martensite and pearlite. On the contrary; his theory demanded the existence of such a colloidal stage intermediate between the homogeneous solution (like martensite) and the undone (separated) mixture (like

pearlite). That assumption of a colloidal intermediate stage was useful also for ordinary chemical reactions. Vaseline, e. g. was uniformly dissolved by ethyl alcohol on the water bath. When the beaker was placed on the table, a white sediment or turbidity was noticed near the bottom of the glass, and this sediment might be mistaken for a solid impurity; but the turbidity spread all through the beaker and possessed considerable stability, being in reality a colloidal solution or a fine emulsion of very small drops of vaseline in alcohol. To this turbid solution which slowly separated into $C_2H_5 . OH$ + vaseline, troostite offered a striking analogy (in the state of maximum turbidity, osmondite). The main interest of the troostite theory was to be found in the circumstance that it offered a hitherto unknown analogy to the colloidal intermediate stages of liquid solutions in the domain of solid metallic solutions. The analogy could, of course, not as yet sufficiently explain all the details, already known or still to be discovered, of processes in which troostite took part. But is was already recognised pretty generally, that the existence and the interaction of several modifications of Fe had to be accepted. The simplification of our views concerning the constituents intermediate between the martensite and the pearlite periods, was also useful. With regard to the observation by Messrs Rosenhain and Tucker of a change previously unnoticed in lead-tin alloys occurring below the eutectic temperature, Dr. Benedicks finally remarked — because Prof. Heyn had drawn attention to this observation — that Rudberg, of Upsala, the discoverer of the multiple melting points of alloys, had also taken cooling curves of lead-tin alloys which he had published in 1830, and that in these curves the re-discovered inversion of Rosenhain and Tucker was distinctly discernible.

In reply to Benedicks, Prof. **E. Heyn** remarked that the colloid-hypothesis, to which as such he was quite sympathetic, could only presume that some body X was segregated in fine subdivision. This hypothesis might be accepted without proof, as long as it satisfied the conditions which every hypothesis had to fulfil, namely that it explained the observed facts without having to be strained, and that it permitted of anticipating new, still unobserved facts. In how far the colloid-hypothesis met these conditions, the future would teach. The assertion, that the body X must be a carbide (Fe_3C), was a different thing. That required a proof. He

was grateful too that Dr. Benedicks had drawn his attention to Rudberg's work.

Mr. **J. E. Stead** (Middlesborough) stated that it would take at least a fortnight to follow Mr. Heyn's review in detail, whereas only about fifteen minutes were then available. He complimented the author on his work, which confirmed his own researches made as early as 1900.

He, the speaker, also referred to the work carried out in Germany by Wüst on Iron-phosphorus, and Iron-carbon-phosphorus alloys. Wüst had found that the eutectic alloy of iron, carbon and phosphorus contained 3 per cent of carbon and 4·7 per cent of phosphorus, which corresponded closely with the alloy which was separated from Cleveland pig iron when in plastic state under hydraulic pressure.

Dr. **W. Rosenhain** (Teddington) proposer, for the purpose of securing the inclusion of a complete international bibliography in Reports on Metallography such as that presented to the present Congress by Prof. Heyn, that Section A should appoint two representatives in each country who should send to the author of the report a list of papers published in their own country or language which were bearing on Metallography. These lists should contain the titles and a statement of contents or subject not exceeding 20 words for each paper. These lists should be sent to the author of the report by a date to be fixed by bim. He thanked Dr. Benedicks for his interesting communication as to the results of metallographic studies.

Prof. **H. Le Chatelier** (Paris), said that he had read Prof. Heyn's report with the greatest interest. The nature of the structural constituents was no doubt of high importance, not only for scientific investigation, but also for the practice of steel production. In this respect the discovery of Osmond had opened a new era. Yet he would not recommend to proceed further in the direction of introducing everyday new constituents. It appeared rather more advisable to diminish their number. It would, he thought, suffice for instance, to distinguish only three groups in steel: osmondite or troostite, martensite, and pearlite or sorbite.

Prof. **E. Heyn** would likewise welcome every simplification. The just proposed simplification would, however, be secured at the expense of metallurgical reality. He would in particular depre-

cate the identification of pearlite and sorbite, and he could hence not consent to the proposal made by Mr. Le Chatelier.

As no other member rose, the Chairman. Mr. Busse, closed the discussion by proposing a vote of thanks to Prof. Heyn for his report.

Special steels (I_2)

by L. Guillet.

Prof. **L. Guillet** (Paris) reminded the meeting of his Brussels report in which he had pointed out that the special steels might, as to their metallographical composition, be divided into pearlitic, martensitic and polyhedric steels on the one side, and such which contained double carbon compounds on the other, but that only the pearlitic and polyhedric steels had any technical importance. To-day he had to add that the polyhedric steels had likewise lost much of their importance. They were applied in special cases only, e. g. nickel steel of 36 per cent, because it did not extend; further nickel steel of 46 per cent, whose coefficient of expansion was equal to that of glass, a fact of great importance for lamp sockets. Hadfield steel had of late also found interesting utilisation, e. g, for certain parts of the track of the Metropolitan in Paris. Apart from these applications polyhedric steels were not in demand on account of their high prices and low elastic limits. Thus there remained for the practice none but the pearlitic steels. The recent advances in their production concerned three points:

1. The introduction of vanadium, utilised particularly in America.

2. The simplification of the thermal treatment. In order to obviate the difficulties connected with hardening at a particular temperature, attempts had first been made to produce steels for which a definite hardening temperature need not exactly be observed. To this class belonged nickel steel of low carbon percentage (0·15), or nickel steel with higher carbon percentage which had, however, to be hardened in oil. Quite recently the tendency had been to manufacture steels which did not require any tempering. Air-hardened steels had been produced which were applied both as tool steels and as materials of construction. The metallographical examination showed that these air-hardened steels were intermediate between pearlitic and martenitic steels. A temperature of from 800 to 950° C. sufficed for their hardening, when followed by simple

cooling in the air. This method had yielded interesting results. Steel of a strength of 70 kg and of an elongation of 18 per cent marked, after air hardening, a strength of 130 or 140 and even 150 or 160 kg/mm^2 and an elastic limit of about 130 kg/mm^2; the elongation was 8 or 9 per cent, and the work done in fracture in notched-bar impact tests 10 kgm.

All these air-hardened steels were Ni-Cr steels, containing from 0·2 to 0·5 and 0·6 per cent of C, from 3 to 7 per cent of Ni, from 0·15 to 1 per cent of Cr, and sometimes 0·1 or 0·2 per cent of V. This was the composition of most of the steels used for the construction of automobiles.

3. The third object aimed at in the most recent time had been the increase in the carbon contents which would yield steels that could be exposed to unusual friction. Those steels contained 0·5 or 0·6 per cent of carbon, 2·5 of nickel and 0·42 of chromium. In concluding Guillet dwelt upon the extraordinary progress accomplished quite recently in the production of copper steels and rapid tool steels. Interesting information concerning these steels might be expected by the time that the Congress held its next meeting.

The chairman thanked Mr. Guillet for his instructive report and announced that Chief Engineer Max Bermann would deliver his experimental discourse on steel testing by sparking in the hall in which Section C was meeting.

Steel Testing by Sparking ($VIII_7$).[1])

Mr. **M. Bermann** (Budapest) briefly explained his method and demonstrated, how the nature of the spark train, produced when

[1]) Chief Engineer Bartel (Budapest), having at the last moment been prevented from attending, had sent in a report on the method of Bermann, which he strongly recommended for workshop practice, without wishing to express any opinion as to its theory. By the aid of a set of analysed standard rods the carbon contents could be determined within 0·01 per cent. The method was especially suitable for determining inequalities in the composition and was superior even to the Brinell test. Mr. Bartel quoted cases from practical experience, in which the spark test had proved valuable and had in a few minutes shown, that the steel was heterogeneous or had not been treated properly. The Bermann test unfortunately did not leave any records and was hence unsuitable as official acceptance test. Mr. Bartel thought that the test might be facilitated by standardising the speed of the emery wheel, the wheel material and the pressure against the wheel, and that the spark test would then find adoption in our metallurgical works and shops.

the test piece was pressed against the emery wheel, permitted of estimating the contents in carbon and further in manganese, tungsten and chromium. In concluding his discourse, he expressed the hope that he had succeeded in demonstrating that differences in the carbon percentage as small as 0·01 per cent could, with the aid of analysed standards, easily be recognised without experience and special scientific knowledge, and that the spark method therefore afforded, at the actual stage already, a simple means of determining the absolute and relative carbon contents of different kinds of iron, and hence a ready check on chemical analyses. Mr. Bermann begged to draw the attention of the Congress to this new method and asked members to examine his explanation of the spark phenomena, being convinced that the spark test would be able to hold its own among the methods of material testing.

The Chairman conveyed the thanks of the meeting to the lecturer for his suggestive demonstration.

(Luncheon Interval.)

The Chairman invited discussion of the report presented by Sub-Committee Ia.

Establishment of International Specifications for Iron and Steel ($VIII_1$).

Dr. von Rieppel not being present the **Chairman** called upon Mr. Webster to present the report.

Mr. **Wm. R. Webster** (Philadelphia) pointed out that the report of the Sub-Committee explained the outlines for the further work of the Sub-Committee and asked the Section to accept the report and to make suggestions. He would be happy to be assured of the approval of the Congress, so that they might continue their deliberations till the next Congress.

Prof. **A. Martens** moved the following resolution:

> "The Vth Congress welcomes the work of Sub-"Committee Ia, approves in general of the principles "laid down in Congress report $VIII_1$ and resolves: "Committee I (Sub-Committee Ia) are invited to con-"tinue their valuable labours in co-operation with the

"National Societies and, if possible, to place before "the VIth Congress definite proposals as to the basis "of International Specifications for Iron and Steel."

Prof. **N. Belelubsky** (St. Petersburg) pointed out that Russia was already in possession of uniform specifications in accordance with the regulations of the Russian Government. He would recommend that the Sub-Committee should not confine its compilations to America, England and Germany, but should include Russia and the other Countries. He moved for an extension of the Sub-Committee in this sense.

Mr. **Leslie S. Robertson** (London) objected that the Sub-Committee could, as a matter of principle only deal with conditions of a national character and could not deal with specifications of a private character, even if they emanated from a government which had laid down its special views concerning these specifications. The specifications to be dealt with by the Sub-Committee had to approved by the National-Associations and had to be issued by commissions, on which the consumers were represented as well as the producers.

Prof. **N. Belelubsky** remarked that Russia had taken up the question of specifications for iron materials many years ago, and that the supply of materials for bridge construction, car axles and rails had uniformly been regulated (in the case of rails already since the Dresden Congress). As regards ingot-iron, technical specifications had been laid down in 1885, — earlier thus than in Germany and Austria. He had himself reported to the Brussels Congress on the extensive series of rail tests on which the specifications had been based, and he would direct the attention of the meeting to the Russian exports of rails, locomotives and bridges. It was thus evident that Russia took a great interest in the work of Committee Ia.

Prof. **A. Martens** pointed out that his motion implied in due fairness an extension of the Committee.

Mr. **Wm. R. Webster** emphasised that every country would have to lay down its own uniform specifications before, other countries could be asked to form. There would be no difficulty in arriving at an agreement as to the supply of good materials.

Mr. **Cartault** (Paris), considered that there were two points of view for the work of the Sub-Committee. The first was to

create a kind of international vocabulary, enabling each nation to find the equivalents of its technical terms in other languages; that would be an extremely useful task. The second object should be to lay down uniform specifications. The realisation of this part of the programme appeared difficult. The conditions of production and of application varied with localities; thus the requirements for rails were not the same in northern and in southern states. The Committee could only draw up general specifications which would have little interest. Too precise a specification would involve grave inconveniences; progress would be retarded because each modification would require a renewed examination on the part of the Committee. It would be better therefore to let the producers and the consumers discuss their conditions and transactions without restraint.

Prof. **F. Schüle** (Zurich) pointed out that the report of the Sub-Committee had not yet been examined by the Committee. It was desirable that the non-producing countries like Switzerland should also be considered, and he proposed that the motion of Prof. Martens be accepted.

Prof. **B. Kirsch** supported the motion which the Chairman put to the vote.

The resolution proposed by Prof. Martens was passed.[1])

[1]) The problem of the international unification of the specification was, on the suggestion of Mr. W. R. Webster, of Philadelphia, informally discussed, in the rooms of Section A, on September 9th at 5 p. m. by a very fully attended meeting. Mr. Webster took the chair in response to the general desire. It was once more emphasised that the different countries had first to agree upon uniform specification, which had so far been done only in Germany, Great-Britain and America. In that case Committee Ia would in each country and for each class of materials only have to deal with one regulation, which would be recognised by a testing Association consisting of producers and consumers (in countries which did not produce iron, only of the latter). The idea that the commissions of the separate National Associations should act after the manner of clearing-houses for the specifications of their own countries, while Committee Ia would be the international clearing-house, met with general approval. It was also recognised that it would be possible, by comparison of such specifications and by their progressive adaptation to marked changes, to avoid hairsplitting regulations, finally to arrive, if only in the course of years, at uniform specifications. It was further generally acknowledged that it was desirable to admit other countries to Committee Ia, in so far, of course, as these countries adhered to the above mentioned conditions. The Secretary General undertook to report to the Council on the co-operation of the representatives of such countries. Several speakers finally explained the actual state of the problem of the unification of specifications in their own countries.

The **chairman** then opened the discussion on the report of Committee 24.

On the Uniform Nomenclature of Iron and Steel ($VIII_2$).

The report, drawn up by Prof. Henry M. Howe (New York) and Prof. A. Sauveur (Cambridge, Mass.); comprised:

1. A polyglot table of the chief classes of Iron and Steel and their production.

2. English definitions of the chief classes of Iron and Steel and of the microscopical constituents of these metals.

3. A glossary of special sizes and shapes of Iron and Steel.

4. Opinions of Societies.

The object of the definitions, the committee reported, was briefly to define the meanings of the terms customary in different languages and to fix the boundaries which separated a metal in question from others, with which it might easily be confounded.

As regards the definitions of the microscopical constituents the authors remarked, that their definitions of the constituents were based upon their well-known and generally accepted properties, and not upon their natures and constitutions which remained controversial.

The chairman of the committee proposed at the same time to adopt the term "metaral" — the analogue to "mineral" — as equivalent for the term "microscopical constituent". The word was more accurate, since certain constituents, such as the graphite of pigiron and the primary cementite of ferro-manganese, were not microscopical at all, while occluded gas and dissolved iron oxide, which certainly were constituents, but hardly "metarals", would easily be distinguished in this manner.

The authors finally stated that some new names like osmondite and troosto-sorbite, proposed by certain investigators, had not been embodied in their table of definitions, because these compounds remained hypothetical.

Prof. **Jos. W. Richards** (South Bethlehem, Pa.) opposed the programme of the Committee which aimed at fixing the current terms as exactly as possible. That meant fixing the actual confusion. Investigators should not lag behind with their designations, they should take care that any novel industrial products were properly named when first introduced.

Steel produced in the electric furnace was such a product of the most recent epoch. On account of its high quality it had so far been sold and offered as crucible steel. A second, less valuable product was obtained from pig iron, which was decarburised in the Bessemer or Martin furnace and then refined in the electric furnace. The report did not propose any definitions for these products. Surely it was the principal duty of a committee for uniform nomenclature to see that such products were scientifically defined.

Coming to the particulars of the report, as it stands, the speaker agreed with the principle embodied in the definitions of blister steel and cast iron, viz that "the essential quality of cast iron is its composition and not its being cast, and the essential quality of blister steel is its composition caused by cementation and not its blisters". Carrying out this same principle, pig iron is the product of the blast furnace, or material similar thereto made in the electric shaft furnace (Hochofen). The committee was inconsistent in giving a narrower definition than this to pig iron, and in giving a definition which does not correspond with general use or logical analogy.

Concerning Steel, M. M. Pourcel and Greiner have submitted a definition which is much more practical than the one submitted by the committee, and the speaker left the discussion of this point to those gentlemen.

The principal omissions which he noted and which he would submit to the further consideration of the Committee were

Electric pig iron, or electric furnace pig iron: Cast iron produced by the reduction of iron ore in an electric furnace.

Electric steel, or all-electric steel: Steel manufactured entirely is an electric furnace.

Bessemer-electric steel: Steel made in an electric furnace using therein the molten product of the Bessemer converter.

Open hearth-electric steel: Steel made in an electric furnace using therein the molten product of the open hearth furnace.

The above were not all of the commercial forms of iron and steel already on the market which the report of the Committee fails entirely to name or to suggest any name.

In conclusion, the report should have proceeded upon other lines, it should have attempted but slight revision of present fixed terms but should have provided liberally new terms for the new products just appearing in commerce, and have proposed proper terms for others likely to appear and as yet un-named.

This work cannot be well done by a large committee, nor by one Society alone. The best way to arrive at a result which would be worth anything would be to request about five influential societies to appoint one member each, the best man at their command, who would with one member appointed from this Society constitute a permanent committee to consider improvements in the present nomenclature of iron and steel, to discuss upon its appearance in commerce the proper name to be given to a new commercial product, and to provide in advance for the systematic and uniform growth of this scientific nomenclature. The members of this committee could be re-appointed each year, and their decisions would be binding upon the concurring societies for use in their publications.

For this purpose, Prof. Richards moved that this society request the

Comité des Forges de France,
Verein Deutscher Eisenhüttenleute,
Jern Kontoret of Sweden,
Iron and Steel Institute of Great Britain,
American Institute of Mining Engineers

to each appoint one member of an International Committee, that the council of this Society appoint a sixth member, and that the object of this committee's labors shall be to revise as far as is expedient the present nomenclature of iron and steel, to discuss and recommend proper names for new commercial iron and steel products, and to provide for the future reasonable extension of this nomenclature upon a scientific basis, with the understanding that the findings of this committee shall be binding upon the concurring societies.

Prof. H. **Le Chatelier** (Paris) distinguished two parts of the work of the Committee. The one part was essentially technical, the other scientific. There was not much to discuss as regards the technical side. Every country had long been making use of fixed terms for its iron and steel products. The tabulation of all

these terms used in different countries was all the more interesting, as the work had been done by men of the highest competency. In this respect the report was a valuable complement to technical dictionaries, and the Committee deserved their sincere thanks for their achievement. With respect to the scientific side the Congress could, on the contrary, act in a deciding capacity, and fix the names of certain microscopical constituents; for great confusion still prevailed in this field. For example, the same constituent was called: Troostite by Osmond, sorbite by Stead, osmondite by Heyn, and martensite by Arnold. The speaker would, therefore, in the first instance, ask the Congress, whether it was not expedient to fix definitely the nomenclature of a certain number of constituents, about which they were already in accord. If that proposal were carried, the numerous metallographers present might come to a decision, which constituents could already be definitely fixed, and which constituents had better be left for further consideration in view of the actual discrepancies of opinion. The speaker finally remarked that he was very partial to the term "metaral", proposed by the Committee. Yet one should only designate by this term something which was homogeneous, in analogy to the use of the word "mineral". Just as granite was not a mineral, pearlite should not be termed "metaral". For the aggregates of microscopical constitiuents another designation should be found. The speaker hoped that the Congress would approve of his proposal, to fix without delay certain scientific designations, which were already in general use in the metallographical literature.

Prof. **A. Martens** concurred. With regard to the nomenclature of newly discovered constituents, however, the opinions and approvals of the National Association would have to be obtained, before the Congress could pass a resolution.

Mr. **F. W. Harbord** (London) remarked that he had only been elected on the Committee, after the greater part of the work had been done, and the report had largely been drafted. He had consequently not been able to discuss the various definitions before their publication, and he regretted to have to state that he was not in agreement with several of the definitions of the report. The definition of "Blister Steel" was a case in point. That term was clearly understood in the English trade to mean wrought iron bars carburised by cementation, of such a degree of purity

in respect to phosphorus and sulphur, that the blister bar should be suitable for remelting, for the manufacture of shear (Schweiß) steel. English Law Courts, would, quite certainly, hold that an undertaking to supply "blister steel" implied the obligation to supply material low in phosphorus and sulphur. In his opinion the report should be referred back to the Committee for further consideration, and Mr. Stead associated himself with him in this question, as it was of the greatest importance that the definitions of the Committee should be in agreement with what was understood and accepted by technical men.

Dr. **V. Misángyi** (Budapest) asked that the Hungarian terms should be added to the tables of the Committee.

Mr. A. **Greiner** (Seraing) recognised and duly appreciated the great value of the report of Committee 24. Yet with regard to the differentiation between "iron and steel", he considered that the simple definition given in the report which he had drawn up in conjunction with Mr. A. Pourcel and which was reproduced from a paper published by one of them in 1869, retained its raison d'être more than ever. This definition was the following:

Iron is differentiated from steel merely by the process of manufacture. Thus every cast malleable metal is a steel, and every malleable metal which is not cast is an iron. They should hence distinguish: 1. pig iron: cast, not malleable metal; 2. iron: malleable, not cast metal; 3. steel: cast malleable metal.

In a remark to be found on page 10 of the report of Committee 24 the reporter raised the objection that what had so far been called "blister steel", would become cement iron from this point of view. That might be so. But the answer was that "blister steel" was fast becoming — if indeed it had not already become — a product of purely historical interest, since $^{9}/_{10}$, if not $^{99}/_{100}$ of the output of blister steel was used as raw material for the manufacture of steel in crucibles; and the days of the crucible were numbered, since the advent of the electric furnace. It mattered little therefore, in practice what they were to understand by the terms "cement iron" or "cement steel".

In support of the nomenclature which he advocated Mr. Greiner quoted a typical remark made by Prof. Ledebur: "Nine-tenths of the output of the German Steel works consist of a metal which practically cannot be hardened. It must hence be assumed that

these works pretend to produce, not iron, but soft steel, in order to justify their designation 'steel works'".

Which other metal, moreover, Mr. Greiner continued, yielded, with very limited proportions of another element — carbon — ranging from 0·05 up to 4·6 per cent, such a variety of products each possessing different and well-characterised physical and mechanical properties! Neither copper, nor lead, nor zinc, nor tin presented so great a number of transformations.

In reply to those who persevered in regarding the property of becoming hardened as the distinctive characteristic of steel, Mr. Greiner would point out, that it would be impossible to retain the designation as steel castings for objects made of a ferrous metal, when those objects were commonly produced from a metal containing 0·10 and less of carbon which stood deformation under the (steam) hammer in the cold perfectly. Such pieces were falsely styled steel castings by the manufacturers and by public authorities. Was this objection not more weighty than the one which had been raised with regard to blister steel? Since it was, in the case of castings, a question of an output of thousands of tons, while the case of blister steel concerned a product of extremely small application. It would hence be conceded that the choice of the property of hardening as characteristic for the differentation between iron and steel could no longer be justified even on the grounds of commercial interests which had led to its adoption at the time when the Thomas process made its appearance. What remained, then, to sustain that differentation? Logic? Certainly not! Under the present circumstances Wedding himself, who had instigated it at the Philadelphia Congress of 1876, would surely abandon it.

Mr. Greiner concluded his remarks by expressing his opinion that the Congress, faithful to the programme, which it had drawn up, would not enter upon an arbitrary amelioration of the actual terms. He believed with Mr. Pourcel, that the Congress would join them in designating as steel all malleable iron products obtained by the process of fusion.

In consideration of the advanced hour, the Chairman adjourned the debate, postponing the vote until the following day.

The meeting was closed at 2,30 p. m.

Second Day of Meeting. Thursday, September 9th, 1909.

The Chairman, Director **Busse**, opened the proceedings at 9—45. a. m. inviting the honorary presidents and hon. secretaries to come up to the platform. He then called upon Mr. **Guillet** to read his report on the work of the Committee on Copper.

On standard specifications for the purchase of copper ($VIII_3$).

Prof. **L. Guillet** (Paris) gave a brief résumé of the report, copies of which were in the hands of all the members. It would be understood that the Committe had been unable to completee its work. But the enquiries addressed to the members of different nationalities had elicited ample and valuable material, and the Committee hoped to submit definitive proposals to the next Congress. Mr. Guillet thought that he might already propose that the work of the Committee should be extended to the various Copper Alloys, bronze, brass etc.

Prof. **A. Martens** supported this proposal by Mr. Guillet and suggested that the Committee on Copper might colloborate with Committee I or Sub-Committee Ia, on uniform specification for Iron and Steel.

Prof. **L. Guillet** did not consider such a collaboration advisable. There was no connection between the methods of iron and steel testing on the one hand, and copper testing on the other, except as to quite general features, such as the shape of the test rods etc. Te following resolution was then unanimously passed:

> "The Congress expresses its best thanks to the "Committee on Copper for their work and approves "of the proposals of the Committee to extend the "scope of their investigations so as to include the "study of specifications for Copper Alloys."

The Chairman passed to the next item on the agenda paper:

Unification of Methods of testing Steam, Gas and Water Pipes ($VIII_6$).

Mr. **A. C. Karsten** (Copenhagen) dwelt chiefly upon the fact that there were no general regulations for pipes, and that this accounted for the differences in the weights and qualities of pipes supplied by different firms. Quite recently this drawback

had been accentuated, by Mr. **Haller** before the meeting of Heizungs- und Lüftungs-Fachmänner (Heating and Ventilating Engineers), assembled at Frankfurt-on-the-Main. The Danish Association of Engineers had attempted to lay down general rules, and the Danish Government Testing Station had conducted extensive experiments under the superintendence of Prof. Hannover. The results of these experiments and the regulations based upon them had been communicated to the Brussels Congress. The continued experiments had suggested some alterations in the rules. The weights had to be modified, the external diameters had been brought in accord with the most recent German rules, and the number of pipes to be tested had been fixed. The specifications as modified by the Danish engineers had been incorporated in the report. Mr. Karsten proposed to submit the specifications to a Committee with the oject of making them the basis of International Specifications.

Mr. **W. Wood** (Philadelphia) proposed to refer the unification of pipes to the already existing Committee I or the Sub-Comittee Ia.

Mr. **Leslie S. Robertson** (London) desired the exclude the question of pipe threads from the resolution. An International Commission on the unification of pipe threads had been constituted in Paris two months previous. It would be undesirable to interfere with the work of this commission by parallel endeavours; the question had best be left to the Paris Commission in accord with which they could act.

Prof. **A. Martens** then formally moved that the problem of the Unification of Specifications of Pipes should be submitted to Committee I with the object of arriving, in conjuction with the National Associations, at an International understanding, excluding however the question of threads.

Mr. **Karsten** having expressed his acquiescence, the resolution of Prof. Martens was unanimously accepted as follows:

> "The Congress takes note with thanks of the
> 'valuable report by Mr. Karsten on the Specification
> "of Wrought Iron Pipes and refers it to Committee I
> "for examination and report to the next Congress,
> "excluding the thread question."

Hardness tests (II_1).

In presenting his report Dr. **P. Ludwik** (Vienna) confined himself to a summary sufficiently explicit for opening the discussion on the subject; copies of the report had been distributed.

The report was divided into three parts.

The first part dealt with the Brinell ball-pressure test as carried out by measuring a) the diameter of the impression, and b) the depth of the cavity.

The measurement of the diameter permitted of working, in general at least, with shallower impressions than were advisable for cavity measurements. The determination of the diameter was especially advantageous in the cases:

1. of hard materials; 2. of small or thin test specimens; 3. when the material was to be damaged as little as possible; 4. when the determination of the surface hardness was particularly desired.

The measurement of the depth of the cavity, on the other hand, offered the advantage of simplicity, since the somewhat elaborate subsequent measurement of the diameter (by means of a microscope &c.) was not required.

The cavity measurement was, with very shallow impressions, possible only with the ball-pressure apparatus of Martens and Heyn. This apparatus hence admitted of making the best use of the advantages of both the diameter and the cavity determinations, presuming that the depth could be determined within about a thousandth of a millimetre. A detailed description of the Martens apparatus was given in another printed Congress report. The apparatus was on exhibition in the building.

The second part of Dr. Ludwik's report dealt with the cone pressure tests which were of a cognate nature.

The cone-pressure test differed, however, from the ball-pressure test, because its hardness number was independent of the load and of the size of the impression, and could therefore be expressed by a single figure. It was thus immaterial on principle, to what depth the point of the cone was driven into the material under examination. In his printed report the speaker had exclusively referred to cone-pressure apparatus for cavity measurements. Among the testing machines exhibited in the Congress building, he had, however, noticed a cone-pressure apparatus

which admitted of an automatic measurement of the penetration; that seemed to be a praiseworthy feature.

The third part of the report discussed the important question of the relations between hardness and strength (especially between hardness and yield point and between hardness and tensile strength). Since that question was intimately connected with problems of very extensive bearing, the speaker contented himself with stating that there could, as a matter of principle, not exist any uniform relation between hardness and mechanical strength, because that relation depended: 1. on the form of the stress-strain diagram; 2. on the shape of the impression.

Yet that statement did not by any means exclude the possibility of deducing — for groups of materials of fairly the same kind and with an approximation sufficient for practical purposes — the yield point and the tensile strength from the hardness, by the aid of a coefficient based upon experience and valid only for that particular group.

This, however, with one restriction: the statement held only for ductile materials, as otherwise the ratio between tensile strength and hardness would materially be influenced also by the cohesion of the material (e. g. in the case of cast iron). That the ratio was independent of the cohesion for ductile materials, was evident from the fact that the tensile strength of such materials could be determined without breaking the test bar, and thus without overcoming the cohesion. It would be understood that hardness tests could replace tension tests to a certain extent only, since the tension test was utilised also for determining the elongation (the tenacity and ductility) of the material, whilst the hardness number did not permit of drawing any conclusions as to these properties.

In cases, however, in which the tension test was merely applied for determining the tensile strength (apart from the elongation), the much simpler and less expensive ball-pressure or cone-pressure tests could in many circumstances be substituted for the tension tests of ductile materials.

In this sense the Austrian Association for testing Materials had, in its last annual meeting, adopted the following resolution: "considering that the tension test (merely aiming at the determination of the tensile strength) may with ductile materials eventually be replaced by a hardness test, it is recommended to con-

duct comparative tension tests and ball-pressure and cone-pressure tests."

The speaker concluded by expressing the hope that the discussion, he had been asked to introduce, would more exhaustively deal with the problems, upon which he had touched, and with cognate problems.

Dr. C. **Benedicks** (Upsala) congratulated the speaker on the success of his method. When they considered the superiority of

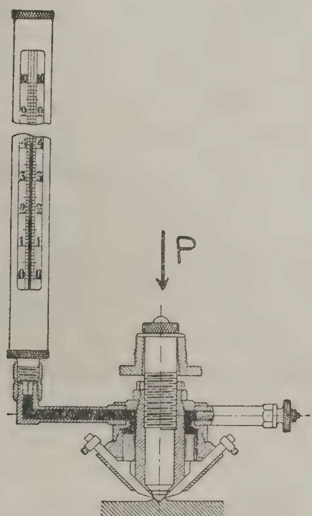

Fig. 5.
Apparatus of the Aktie-Bolaget "Alpha" of Stockholm, for Cone-Pressure Tests.

the Brinell test over the old method of Calvert and Johnson who, they would remember, had used a truncated cone of hard steel as penetrating tool, they could not but wonder at the new success of the cone-pressure test. Dr. Ludwik could claim the credit of having established for this test the validity of Kick's law of proportional resistance. As regards the ball impression, he himself (Benedicks) had not found Kick's law applicable. If they made a test with a ball of 5 mm diameter and a load of 500 kg. they would find a certain hardness number. If Kick's rule were applicable, they should want a load of 2000 kg for a ball of 10 mm

in order to realise the same number; but they did need in fact 3000 kg. He had discussed an experimental enquiry into this problem in his doctor dissertation. He would also point out that the Brinell method was much more suitable than the Ludwik method for comparative tests of materials of very unequal hardness; it could hardly be doubted, that it was for materials of average hardness that the Ludwik test was particularly suitable.

Mr. **J. O. Roos of Hjelmsäter** (Stockholm) dwelt upon the large range of applicability of the Brinell test and expressed the hope, that the cone-pressure test of Ludwik would likewise render excellent service on account of the independency of the hardness number obtained from the load applied. Yet he would submit, that it did not appear advisable in practice to make the depth of the penetration the criterion, since a kind of marginal extrusion was formed which complicated the measurement. The "Alpha Company" of Stockholm had worked out a good device for taking readings; the device could easily be added to any ball-pressure apparatus. The results obtained with the aid of this machine confirmed the independency of the cone-pressure hardness from the load, as found by Ludwik.

Colonel **C. Ramos y Comas** (Madrid) did not think, that the tensile strength could be deduced from the hardness. The ball-pressure test was very convenient for determining, in acceptance tests, the homogeneity of the materials, especially of rails.

Prof. **S. Rejtő** (Budapest) contested the statement that Kick's law of proportional resistances did not hold for ball-pressure tests. It would appear that Benedicks had measured the depth of the cavity and not the angle of penetration, the angle at the centre of the spherical impression.

Prof. **L. Guillet** (Paris) remarked that so far the determination of the hardness or the tensile strength had been spoken of as the main object of the Brinell test. That test had been used for another purpose in the works with which he was connected, namely, for ascertaining whether the thermal treatment of a specimen had the desired result. The ball-pressure test permitted of making this verification, whatever the dimensions of the piece and without spoiling it for ultimate use. The speaker also stated that there was an intimate relation between the coefficient, by the aid of which the breaking load was deduced from the hardness test, and the

structure of the metal; pearlitic nickel steel had a coefficient which differed from that of martensitic or polyhedric steel. With respect to the applicability of the Brinell test to copper, he would refer the meeting to the memoir by himself and Mr. Révillon. The experiments which they were couducting were favourable to the ball-test. As regards the dimensions of the ball, especially for copper alloys, the structure and the dimensions of the crystals had to be taken into consideration. Particularly in the case of anti-friction metals, normal balls would only affect a small zone of crystalls, and that would lead to irregular results.

Dr. **C. Benedicks** (Upsala) remarked in reply to Prof. Rejtő that he had considered the penetration angle in his measurements.

Prof. **S. Rejtő** enquired whether Dr. Benedicks had, in his calculations, perhaps taken the calotte instead of the circular area; that might explain the contradiction.

Dr. **C. Benedicks** objected that it was immaterial, for geometrical reasons, whether the calotte or the circular area were taken into consideration, as long as the angle of penetration remained constant.

Dr. W. **Rosenhain** (Teddington) pointed out that the cone-pressure test was apt to give uncertain and indefinite results, if the point became in the slightest way rounded. He mentioned that he had himself obtained excellent results by determining the hardness from the height of rebound of a small cone fitted with a spherical point, which was dropped on the specimen.

Prof. **H. I. Hannover** (Copenhagen) thought that the rebound method, just mentioned by Rosenhain, could advantageously be applied only for very particular materials, e. g.. for bodies like rolls, which were already finely polished and which would be damaged by a Brinell or a Ludwik test. The property which would be determined in this way was, however, not the same as that about which the other hardness tests afforded information, as Mr. Rosenhain had already pointed out. Though this method might be very useful, when they wished to ascertain, whether the material of a roll was uniform throughout its crust, this method hardly fell within the scope of the actual discussion.

Prof **B. Kirsch** (Vienna) was afraid that the great number of tests under examination would involve a waste of their efforts. It was not necessary to create a cone-pressure test; it would be more correct to apply the Brinell ball-pressure test as widely as

possible. In this respect the Martens apparatus seemed the most perfect. The rebound method could only be used with perfectly elastic bodies.

Prof. **A. Martens** believed that the main object of the investigation of materials should be to elaborate a method which would yield practical results, i. e. results which ensured equal values for equal materials.

Prof. **N. Belelubsky** mentioned that the ball-pressure test had been applied in Russia for seven years; many experiments had in particular been made for the Russian State Railways.

Prof. **E. Heyn** (Gr.-Lichterfelde) briefly described the

Martens Ball Hardness Testing Machine (report II_2).

The Brinell hardness number H, he stated, was the pressure referred to the unit area of the impression calotte

$$H = \frac{P}{\pi D h}$$

In calculating the area of the calotte the depth of the cavity h was actually deduced from the measured diameter d of the impression. In doing this it was tacitly presumed that the radius of curvature of the spherical calotte was equal to the radius $\frac{D}{2}$ of the unloaded ball.

This presumption was not justified. The radius of curvature was greater than $\frac{D}{2}$ and the Brinell hardness number was thus referred to an imaginary spherical impression which was not actually existent. From the diameter of the impression d a depth of cavity h was deduced, which was not existent either. It seemed therefore preferable to measure the depth of the penetration directly. The Martens hardness testing machine had been designed with this object. Prof. E. Meyer had proposed to define the ball-pressure hardness as the mean pressure acting upon the unit of the impression circle.

This method avoided the elaborate calculation of the spherical surface. Yet it laboured under the difficulty that the diameter d had to be measured, and Meyer's investigations further led to the function $P = ad^n$, so that two constants would have to be determined. In the Martens machine the ball-pressure hardness was

determined for very small values of P (load), because with the low pressures the relation between P and h was very simple, rectilinear. Prof. Heyn explained the advantages af the apparatus and discussed the results which it had yielded.

Prof. **E. Meyer** (Charlottenburg) objected that the curve for the relation between P and h was a straight line only for very small values of P. To use this rectilinear portion of the curve for the estimation of the hardness, was as arbitrary as the rule of Brinell which specified a load of 3000 kg.

Prof. **E. Heyn** replying: "The objection of Prof. Mayer is not valid. In the Martens machine the strength is not determined with respect to an arbitrarily selected point of the curve; for within the range $P = f(h) = C \cdot h$ the pressure P and the depth h may be varied at will, the resulting hardness number will always be the same." The application of a small depth of penetration was moreover consistent and not arbitrary, if they wished to know the original skin hardness as, for instance, in metals for bearings. If they applied great penetration in such cases, the resulting hardness would be that of the material after it had undergone a considerable amount of cold-working by the ball, which hardened it. It was, of course, impossible, whatever apparatus were used, to get over the natural law that the relation $P = ad^n$ or $P = f(h)$ could no longer be expressed by a straight line when the pressure P increased. But it should not be overlooked, that the above relation implied the increase in hardness which the material experienced when the pressure was increased. For this reason the relation was valuable only in cases, when they actually desired to obtain an indication of the change of hardness under pressure, but not in cases in which they wished to estimate the resistance which a material would, in its original state, oppose to the penetration of a body.

Prof. **S. Rejtő** (Budapest) entirely agreed with Prof. Heyn's exposition. Accepting this, however, he concluded that the methods Martens. Heyn and Meyer were not contradictory, but complementary, and that both might therefore find practical application. When, for instance, the greatest admissible load on a bearing was to be determined, the method Martens-Heyn would answer; but when the degree of wear of a bearing was to be determined, the application of the method Meyer would be justified.

Mr. **J. E. Stead** (Middlesbrough) stated that he had used the Brinell machine for several years; recently he had found it very useful in various directions.

The "Shore" method rebound, mentioned by Rosenhain was very useful for determining the various degrees of hardness in spur-wheels and other gear. All the teeth could be successfully tested under the machine, and the degree of hardness of each could be ascertained. All motor-car gear wheels could be tested in the same way. Some tool manufacturers in Sheffield also used this hardness test method, and tools which did not give the necessary rebound were returned to the smith for retreatment.

Prof. **E. Heyn** stated that, in supplementing his report on the development of metallography, he had to dwell upon the great loss which metallographical science had suffered by the death of Dr. Sorby whose well known metallographical researches had formed the starting point of metallography. He was anxious to express his regret that he had not, at the time, known of Dr. Sorby's death. He was convinced that all the members were profoundly affected by this great loss.

The **Chairman** asked the members to rise in honour of Dr. Sorby. (This was done.)

(Luncheon Interval.)

The Chairman called upon Dr. Ludwik to conclude the discussion.

Dr. **P. Ludwik** (Vienna) said that he could only refer to a few points as the hour was so advanced.

With regard to the remarks of Dr. Benedicks he had to reply, that Kick's law of "proportional resistances" was valid, not only for the cone-pressure tests, but also for the ball-pressure tests; that was proved by the experimental researches of Eugen Meyer, Harold Moore, Rasch, Rejtő, Stribeck and others. The apparent deviations from the law which Benedicks had observed, were probably attributable to accessory influences (occasioned by cold-working, skin hardness, dimensions of test specimens &c.).

The cone-pressure apparatus of the Aktie Bolaget Alpha of Stockholm, designed for automatic measurement of the diameter,

to which Mr. Roos had drawn attention, seemed likely to prove very useful. As regards the errors which according to Rosenhain would arise from the rounding of the point of the cone, he would refer the meeting to the literature on the subject. By the aid of a control ring which was fitted to the cone-pressure apparatus for depth measurement, such errors would easily be discovered and allowed for. That diameter measurements were preferable, with small cone penetration, to depth measurements, had been pointed out by himself (Dr. Ludwik).

He had been very glad to hear Mr. Stead's statement that ball-pressure and cone-pressure tests had been adopted by metallographers. Prof. Hannover had demanded to leave rebound methods altogether out of question in discussing hardness tests. As to this point Dr. Ludwik reminded members of the experiments of Turner who had found, that the elastic properties exercised a decided influence on the height of rebound (oak wood would appear to be "harder" than copper, rubber as "hard" as rail steel). All the same, such methods might be utilised for homogeneity tests and even for comparative hardness tests of materials fairly of the same kind, in particular hardened steel.

In this connection the speaker pointed out, that the very interesting discussion on hardness tests had once more proved that different methods of determining hardness might advantageously co-exist, both in pure science and in applied science, since different objects naturally called for different methods of testing.

The **Chairman** having conveyed the cordial thanks of the meeting to Dr. Ludwik read the following resolution which stood in the name of Mr. Hönigsberg, of Vienna, and which was unanimously passed:

"The Congress requests the Council to arrange that "the next Congress, in conjunction with the problem of "the determination of hardness by ball-pressure or cone-"pressure tests, receive reports on uniform tests for the "resistance of materials to Mechanical Wear, and that the "Council consider the advisability of referring this problem "to a committee."

The Section proceeded to the discussion of the chief problem:

Cast Iron.

Tables of Results of experiments on the Strength of Cast Iron with Test Bars of various Cross-Sections, separately cast or cut from the casting (V_1) by Sulzer Brothers, Winterthur.

Mr. F. **Meyer** (Winterthur, Switzerland) confined himself to a few remarks, as the report was in the hands of members. Every foundry man, he pointed out, knew that the chemical composition of cast iron gave certain indications of its physical properties, and purchasers of iron relied upon analyses. They were fully aware, on the other hand, that samples of pig iron of exactly the same analytical compositions might possess very different strengths, and that the value of the iron was not alone determined by the analysis. Certain properties in iron depended upon the method of treatment. Experience, confirmed by the results of the experiments by Messrs. Sulzer, established the predominant influences of temperature, during melting and casting as well as during cooling. These influences might be more marked in different castings from the same ladle than the analytical differences in these castings. It was hence not admissible to draw conclusions as to certain mechanical properties from the results of technical analyses. Metallography, which had a severe task in dealing with castings, could not help them over the difficulties either. The two tables of the report demonstrated how misleading the indications might be, especially in separately cast thin test bars. Whoever desired to make sure of the properties of his castings would therefore have to conduct experiments like those described.

Mr. **Greiner** (Seraing) was of the opinion that the question of testing castings had not been well understood. The experimental results, no matter whether based upon chemical or upon mechanical tests, nerey gave indications as to the properties of a casting. The treatment was the chief thing, and the knowledge of the foundry man played an important part in the quality of the casting. Internal stresses might destroy a piece in use whose material had stood the tests. Thus it was not so much the quality that offered a security against fracture in the cylinders of a gas engine, as the skill which the foundry man applied in order to avoid internal stresses.

Dr. **R. Moldenke** (New-York) gave a brief abstract of his official report.

On the Unification of the Methods of Testing Cast Iron (V_2)[1])

Dr. Moldenke was not quite in agreement with Mr. Greiner. It was no doubt impossible to judge the quality of a material as little homogeneous as cast iron from the behaviour of a separate or a cast-on test bar. Cast iron was a mechanical mixture of steel with carbon and other elements like P, S, Mn, &c. The strains in the casting could not be determined without breaking it. It was hence necessary, and this was confirmed by the most recent researches, made in Germany and America, to examine the quality of the material when a casting was to be estimated, and to insist that suitable materials were used in casting.

Mr. **A. Greiner** objected that in practice good castings were very often produced from an iron whose chemical analysis later on was not considered satisfactory.

Dr. **R. Moldenke** thought that they could not speak of bad cast iron; for an iron could only be relatively bad, with regard to its destination. Dr. Moldenke finally moved the following resolution which was adopted:

> "The Congress recommends to refer the problem
> "of methods of testing cast iron (dealt with by Com-
> "mittee 25) to Committee I."

The Chairman directed attention to the interesting report by Prof. M. Rudeloff.

Influence of High Temperatures on the Mechanical Properties of Metals (VI_1)

the author of which was unfortunately prevented from presenting his report. On the motion of Mr. M. Krause (Berlin) the following resolution was passed:

> "The Congress takes note of the excellent report
> "by Prof. Rudeloff and warmly thanks the author for it."

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[1]) The official report drawn up by Dr. Moldenke as Chairman of Committee 25 could only be printed after the Congress. It appeared in Nr. 13 of the "Proceedings".

Electricity and Magnesium in their relation to Mechanical Testing.

Prof. **L. Guillet** drew attention to the report by Mr. A. Grünhut and Dr. F. Wahn (of Vienna) on:

The utilisation of the Electric and Magnetic Properties of Materials in conducting Mechanical Tests (VII_1)

and to the report by Mr. E. Rasch (Gr.-Lichterfelde) on:

Method for Determining the Elastic Strength Limit by means of Thermo-electric Measurements (VII_3)

and opened the discussion on the bearing of these questions. In his opinion the measurement of the electric conductivity would permit of a more rapid and easy recognition of the properties of materials than mechanical tests, particularly in the examination of special steels. He moved for the appointment of a committee to enquire into these problems.

Prof. **P. Weiss** (Zürich) then communicated a résumé of his report, copies of which had been distributed, on:

Ferromagnetism and the Study of Metalls and Alloys (VII_2).

He showed that if magnetic criteria were not yet utilised to their full extent, the fault rested with the imperfections of the theory and of experimental technics. He indicated what he had done to fill up this double gap, and explained the precise nature of the transformations of iron. Contrary to the opinion so far held, the α and β states did not represent two distinct phases; the γ state, however, was a novel phase different from the phase which comprised both the others. The speaker finally pointed out, how some still doubtful points of the system iron-carbon could magnetically be studied.

The **Chairman** put to the vote a resolution moved by Mr. Guillet, which was accepted in the following terms:

> "The Congress recommends the nomination of "a Committee for studying the use of the electric "and magnetic properties of metals in testing "materials."

Dr. **W. Rosenhain** (Teddington) presented his report on.

Slag Enclosures in Steel (I_4).

Offering a brief summary of his report, which emphasised the great importance of slag enclosures on the behaviour of metals, the author stated that the detection of the enclosures was a comparatively easy thing. The most direct method was an examination of a micro-section of the material.

In the case of rolled and forged materials the section should be longitudinal, since a transverse section would present the enclosures as very minute, dark spots which might easily be overlooked. The origin of the enclosures was still obscure, although the various researches had thrown much light upon the nature of the enclosed impurities. Stead had suggested that the enclosures in steel resulted from the introduction of oxygen into the steel during the melting or the teeming process, and thought that the complete protection of the molten metal from the oxygen would be a remedy — though difficult to realise in practice — against the formation of silicates But Dr. Rosenhain himself believed that steel was also liable to contamination from numerous other causes, during the melting and on its way from the converter or furnace to the ignot-moulds, and that it would be necessary to guard against these changes as well. The speaker finally pointed out that the enclosures were far more dangerous in steel (especially if embedded in the pearlite) than in wrought iron. Every slag enclosure had practically to be considered as an internal fissure, and the study of these impurities was hence of the highest importance.

Prof. **L. Guillet** (Paris) agreed as to the importance of this study of the slag enclosures which excercised the greatest influence on the mechanical properties of steel. He quoted the case of some boiler plates. The plates gave a tensile strength of 42 kg/mm² and an elongation of 20 per cent, and were therefore passed and delivered. But fissures developed subsequently. The impact bending tests, both of bars taken directly from the plate and of thermally prepared bars yielded poor results. It was found that the material contained slag enclosures which led to fracture. Impact tests were hence demanded for the acceptance of further supplies.

In concluding Mr. Guillet recommended a careful study of the problem and moved a resolution to this effect.

Mr. **J. E. Stead** (Middlesbrough) confirmed the statements under his name given in the paper. He had suggested casting all steel, if possible, without allowing the air to impinge upon it. It was wrong to expose the metal to oxygenate after producing it with extreme care. The action of the oxygen in the air led to the formation of slag enclosures, particularly by combination with the manganese and silicon; some of these were eliminated, but others remained in the steel, and these were detrimental.

He thought it was premature to conclude that fracture continued from the slag into the neighbouring metal, and gave as an illustration the case of enamelled ware, the enamel of which cracked, no crack being transmitted to the iron underneath it.

Mr. **Segré** (Rome) expressed the opinion that the frequent serious instances of corrosion of locomotive boilers were a consequence of slag enclosures. Proposing to charge a committee with the study of this question, he considered that this problem like others concerning the testing of rolling stock should be attacked metallographically, and he drew attention to the physical, mechanical and chemical researches conducted by the Istituto Sperimentale of the Italian State Railways. In this connection the speaker referred to the examination, by the State Railway Department of track rails, which had not given satisfaction, with respect to their surface hardness and composition. The Brinell machine had had especially to be modified for this purpose, and hundreds of kilometres of rail track had already been examined in this manner. Mr. Segré handed to the Chairman a description of his apparatus as well as a report by the Istituto Sperimentale on their ball-pressure tests and on the physico-mechanical and chemical tests of the Italian State Railway Department.[1])

The Chairman having put the motion of Mr. Guillet to the vote, this motion was carried in the following terms:

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[1]) Together with these reports Mr. Segré presented to the Chairman a report by the Istituto Sperimentale of the Italian State Railways on their method of testing the materials for their electric plant (for telegraphy, illumination and electric traction), as well as a description of the electrotechnical laboratory of the Institute and their apparatus for determining electric resistance.

A note added to the report suggested to create a special section of the International Association for testing the materials of electrical construction.

"In pursuance of the communication of Mr. "Rosenhain, which emphasises the importance of slag "enclosures in metallurgical products, the Congress "recommends the appointment of a Commission for "the purpose of studying methods for determining "the enclosures and their influence on the mechanical "properties of metallurgical products, and for the "study of the question in the whole."

The Chairman adjourned the meeting of the second day at 2.30 p. m.

Third Day of Meeting. Wednesday, September 8th 1909.

The Chairman, Director **Busse**, opened the proceedings at 9.45 a. m. and called upon Prof. Kirsch who wished to make an announcement.

Prof. **B. Kirsch** (Vienna), drawing attention to his report on:

A New Mirror Apparatus for Measurement of Elasticity ($VIII_4$)

invited members to examine the apparatus which was on exhibition in the lower rooms of the building; he would be glad to give explanations.

The Section proceeded to the discussion of the chief problem:

Endurance Tests.

A letter was read which had been received from Mr. J. E. **Howard** (Watertown, Mass.), who had drawn up the official report on:

The Endurance of Steel to Repeated Stresses (IV_1).

Mr. **J. E. Howard** regretted not to be able to attend the Congress. He therefore wished to point out in this letter that his report contained observations, which would explain some of the phenomena of endurance tests, but which could not account for others. It was chiefly owing to this imperfection of our knowledge, that we were not yet able to interpret all the characteristic features of endurance tests, in which metals successfully withstood repeated stresses. The experience of members should enable them to clear up some of these points.

Prof. **F. Schüle** (Zürich) gave a summary of the report presented by himself and E. Brunner on

Quality Tests and Endurance Tests of Copper Wires (IV_2).

He emphasised once more the influence which the radius of curvature exercised in these tests. An 8 mm wire of hard copper had, under a tensile stress of 2 kg/mm^2 and a bending stress of 8 kg/mm^2, shown almost unlimited strength when the radius of bending was 4 m; whilst they had been able to break copper of medium hardness, or soft copper, or hard tinned copper, in endurance tests when applying the greatest radius of bending and the smallest stresses.

Prof. H. **Le Chatelier** (Paris) welcomed the opportunity which Howard's report gave them for discussing endurance tests. This was undoubtedly the most important of all the questions submitted to the Congress; for the resistance to alternate stresses was of the highest importance in many industrially applied machines. Although the question had been raised by Wöhler, fully fifty years ago, there had so far scarcely been any practical investigations. The reason was easy to understand. Rupture tests, hardness and fragility tests counted by the millions, whilst the endurance tests hardly came up to hundreds. If they could not accelerate the rapidity of these tests, they would have to wait for centuries until they had arrived at the point which they had reached by other methods of testing. These experiments were indeed extremely laborious and expensive; some of the experiments mentioned by Howard had to be continued for a hundred consecutive days. The motive power required for them was in itself an important item. It appeared hence necessary to look for other methods, if they desired to make a little more rapid progress in endurance testing. The object of his remarks, was, in fact, to direct the attention of the Congress to novel ideas which were not yet completely settled, but which should without delay be submitted to a precise experimental control.

"Perfect elasticity" the speaker continued, "is a fiction. It does not exist in any of the materials at our disposal. In admitting its existence we content ourselves with an approximation, sufficient certainly for some practical applications, for instance, in the case of metals subjected to static stress as in metallic structures, but

failing in others. If the existence of an elastic limit were rigorously exact, there would be no question of alternate stress; a metal woud be able to withstand alternating stresses repeated for any number of times, as long as the limit were not exceeded.

Every deformation of a body, however small, in fact gives rise to three distinct phenomena. When the stress which had called forth the strain ceases, we observe first a rapid return of the metallic piece to its primitive dimensions; that is the manifestation of elasticity. But the specimen does not come back exactly to its initial dimensions; we can recognise this by means of methods of high precision. The specimen afterwards left to itself continues to undergo a slow deformation, approaching its initial dimensions more completely; these are viscosity phenomena. The specimen finally keeps a permanent deformation (set), extraordinarily small if you like, but not rigorously nil. These residual deformations are of an absolutely negligeable magnitude compared to the elastic deformations; they do not amount to the thousandth part of the latter, and they are therefore without importance in the static use of metals. But the repetition of the deformation can, by totalising these parasitic phenomena, negligeable so far as a single deformation in concerned, finally produce a profound alteration of the metal and even lead to its fracture. That is the elementary factor upon which the rupture of metals under alternating stress seems to depend.

The direct measurement of these non-elastic deformations is extremely delicate. It is impossible with the apparatus at present at our disposal for the deformation by simple tension under the conditions under which mechanical tests of metals are usually conducted. But they can easily be observed, when we study the deformation ensuing in fine and very long wires under tension; this method of observation does not lend itself, however, to the study of metals in the state in which industrial works supply them.

Mr. Guillet, Secretary of the Faculty of Sciences in the University of Paris, has devised a really practical method for the study of these phenomena, a method which can be applied without difficulty in all industrial laboratories. It has the advantage moreover of permitting the use of metals as bars in the cast or rolled state, welded, forged or submitted to any thermal treatment. The method is hence directly applicable to the study of industrial products.

The principle of this method in the following: Independent of the residual elongation the viscosity of the metals manifests itself by the damping of the oscillatory movements which is easy to observe. We take a bar, bent to a U, like a tuning fork, or a straight bar which is firmly gripped. We bend the bar by a definite amount and leave it to itself; the bar will begin to assume a vibratory movement which gradually dies out. We determine the rate of decrement in the amplitude of the oscillations, either by direct observations, or, more simply perhaps, by producing records on a smoked drum or by photographic methods.

The first experiments by Mr. Guillet have at once brought out two very important facts.

1. Two metals, very similar in their chemical compositions and in their mechanical properties, e. g. a weld iron and a very mild ingot-iron, may shew damping coefficients differing in the ratio 1 : 3. This test thus indicates a property which the so far employed methods fail to reveal.

2. The viscosity of the metal changes in the same measure as the metal is altered by the repetition of alternate stresses. In the habitual method of alternate stress application we see nothing as long as the metal is not completely broken; the watching of the damping, on the contrary, enables us to follow the progressive straining long before fracture ensues.

Finally this method of observation may very simply be combined with a rapid and economical process for developing alternating stresses. For the vibratory movements necessarily set up alternating strains, and they offer the great advantage that they can be maintained at an extraordinarily small expenditure of motive power. Mr. Guillet has devised a very elegant arrangement for maintaining, by electrical means, vibratory movements of strictly defined amplitude. The description of this apparatus has been published in the Revue de Métallurgie (vol. VI, page 885, 1909). The same experimental arrangement thus permits of calling forth a progressive straining of the metal by the repetition of stresses, and of measuring at every moment the viscosity related to this strain. This method of testing requires apparatus which are ten times less expensive that the apparatus actually in use; it permits of conducting the experiments ten times more expeditiously, and of beginning with the observation of the strain after ten times a

smaller number of alterations. The novel experiments are therefore a thousand times less expensive than the old ones, and that figure may possibly be multiplied.

All the same we should not yet exaggerate the importance of the results which we may expect from this new method. We cannot so far assert that it will solve, in a decisive manner, all the problems which the resistance of metals to alternate stresses offers. Yet we can affirm, without fear of error, that it will, in one way or another, produce very interesting results. All the properties of bodies are in fact functions of a very small number of distinct elementary factors. The novel discovery of one of these factors and of a method of its measurement always leads to consequences of incalculable importance. I need only remind this Section of the revolutions which have been brought about in metallurgical industry by the study of the chemical composition by analysis, the study of the structure by metallography, of the tenacity by tensile tests, of fragility by notched bar impact tests. It is certain that the study of viscosity by vibration tests will likewise open up new horizons, though perhaps in directions different from those in which they are looked for.

Here is, for instancc, a curious fact that these researches have already brought out. Prof. C. E. Guye, of the University of Geneva, has, in his studies of the variation of viscosity in very fine wires with temperature, observed that the viscosity increases very rapidly with the temperature. That observation suggests the question, whether the resistance of metals to alternate stresses does not rapidly decrease with the elevation of the temperature. The frequent cases of fracture in the parts of power engines which are heated by the steam cannot be explained by a diminution in tenacity. For according to the old experiments of Mr. André Le Chatelier, which have repeatedly been verified since their publication, steel is a more resisting material at 200° C. than at ordinary temperature, and yet in practice it will not so long remain fit for duty.

These same experiments of Mr. Guye show that, though all the metals display like steel an increase of their viscosity with temperature, the law is not the same for all of them. In the case of gold, silver, copper, platinum the curve is continuous and approximately parabolic. In the case of steel we observe a well

marked maximum at the temperature of 180° C. and a minimum at 240° C. This fact seems to be related to the well-known anomalies which iron presents near those temperatures, and which are generally classed under the vague and little exact denomination of "blue heat" fragility. It is true that these phenomena manifest themselves at higher temperatures than the perturbations of the viscosity which Mr. Guye has discovered. But we have to consider that the strains developed in the viscosity experiments attain only a very small fraction of the elastic limit, while the strains in the blue heat brittlenes exceed the elastic limit, since they produce the permanent deformation of the metal. The critical temperatures may be a function of the magnitude of the produced strains."

After having shown diagrams explaining the results of the experiments with copper and with steel, the speaker expressed the wish that, by the time of the next Congress of the International Association, this method of testing would have been submitted to critical examination in different laboratories and different countries.

Prof. E. **Heyn** thanked Mr. Le Chatelier for his interesting communication and wished to remark that the problem of endurance tests was intimately coupled with two names: Wöhler and Bauschinger, whom they should always remember with gratitude. The Guillet experiments on the vibrations of metals and on their damping offered a very high interest, and they would look forward to further information at the next meeting of the Congress.

The **Chairman** invited discussion on the chief problem of

Impact Tests.

Mr. **G. Charpy** (Montluçon), in opening the discussion, referred to his report, copies of which had been distributed, on:

Impact Tests of Metals (III_1).

His object had been to devise means of arriving at a practical test. In spite of the great number of publications on Impact tests, many questions remained open. Yet the conviction had become general that these tests offered industrial interest. They appeared still too complicated, however, for the exact determination of the influence of all the factors which came into play. To obviate the difficulties it had become necessary to regulate certain details in

a uniform manner which was based upon an arbitrary, yet precise understanding. If the results thus obtained did not possess a signification which was perfectly defined scientifically, they were at least inter-comparable, as was the case with all the other practical tests. It was equally important for the practice to determine the correlation between the results of the tests and the usual properties. From this point of view the speaker suggested two proposals:

1. A typical method of testing should be established which could be recommended as a comparative method and which, above all other things, admitted of making use of somewhat the same language. The preparatory work for such a type of tests had already been supplied in all its details by the German Association under the direction of Prof. Martens. Certain minor details might, if necessary, be modified; the method could then be placed at everybody's disposal and be recognised as a comparative method.

2. This typical method having been fixed, a committee should be nominated which should compile the results of experience gained in the practical use of materials, in order to establish a correlation between the mechanical properties as revealed by these tests and the behaviour of the materials in use.

Prof. **F. Schüle** drew attention to an important point which, in his opinion, stood in the way of adopting, in its integrality, the method of Ehrensberger's report which Mr. Charpy proposed as typical. It was the question of the apparatus. It was not possible to specify one single apparatus, such as the Charpy pendulum hammer, for all the comparative tests. There might be other apparatus which yielded equally good results. The speaker was himself making use of an Amsler apparatus which recorded the velocity of the falling tup in a perfect manner. The diagram of the work done in fracture was recorded on the drum, and the height of fall could conveniently be adjusted in this apparatus.

Mr. **G. Charpy** did not consider, that it was indispensable to recommend one particular apparatus for all the tests. It would be sufficient to lay down the general conditions which the machines had to satisfy. The mode of operation would be as in the case of ordinary tension tests which were performed on machines of very different systems, whose comparability had previously been verified.

The most important conditions to be defined in order to secure comparable results of impact tests appeared to be the following:

1. The rupture should be effected at one blow; it should be possible to measure both the energy absorbed as well as the energy remaining in the tup.

2. The dimensions and the shape of the tup as well as of the supporting knife edges should be determined.

3. The dimensions and shape of the test piece should be fixed. The German test bar of 30 by 30 mm provided with a rounded notch should be recognised as standard test bar. This bar would not suffice for all the tests, notably not for experimenting with small pieces; a smaller test bar should likewise be recommended, therefore, whose dimensions should however rigorously be deducible from those of the standard bar. The fulfilment of this condition had been rendered possible by the experiments of Mr. Révillon, who had endeavoured to deduce a law for deriving the dimensions of other test bars from those of a given bar. In most cases it would be sufficient to adopt a small bar bearing the ratio 3 : 1 to the standard bar. Special conditions should also be fixed for testing sheet metal. The test piece should have the thickness of the sheet, and the notch should be normal to its surface.

Referring to the joint report by himself and Mr. Brunner on

Notched Bar Impact Bending tests (III_2).

Prof. **F. Schüle** (Zürich) remarked that the specific work of rupture should be calculated, not per unit cross section, but per unit volume, that was to say, the unit volume of the material which was strained beyond the elastic limit. That quantity was independent of the depth of the notch. The method would enable them to study the influence of the shape of the notch.

The volume of the material which had been strained beyond the elastic limit was easily determined when the test bar had been polished on the sides. When the yield point was exceeded, the polished surface appeared dim.

Mr. **Chartiée** (Paris) thought that the proposed form of test bars was well suited for special steels and for ordinary weld steels and rolled steels of first quality, but would be too expensive for

common rolled steel, notably such as used for bridge and iron structures. For those steels were rarely homogeneous and required repetitions of the impact test. It appeared desirable to fix, in addition to the standard bar proposed by Charpy, another form, which could readily be prepared at small cost; it would, however, be understood that in all cases of disagreement between supplier and purchaser, the decisive tests should always be made with the standard Charpy test bars as approved by the International Association.

Prof. **Heyn** pointed out, that the plenary meeting was drifting into doing committee work. The numerous points which had to be observed and fixed in the establishment of a comparative test could not be made the subject of discussion by the Congress. Prof. Heyn then supported the pronouncement of the German Association in favour of the selection of one machine. As long as the influences of the different designs were not understood, that factor, which would render the comparability questionable, had to be eliminated. For this reason the Committee of the German Association had recommended the exclusive use of the Charpy machine.

Mr. **Charpy** opposed the suggestion of Prof. Heyn, that the discussion of the details of the tests should once more be referred back to a committee. It was urgent to come to such a solution that the question might pass into the domain of the industrial practice; it should not again be shelved for several years. It had been the object of his report to fix the test conditions, although he perfectly recognised that certain details could not yet be settled and would have to be reserved for future discussions. Sufficient guidance for the conduction of tests was needed at the present time in order that comparable data could be obtained, of which the committee, which he proposed in the second instance, could avail itself. The test conditions which the Congress had to recommend, would be authoritative for those establishments which wished to carry out impact tests and which had no particular reasons to employ other experimental methods. As regards the apparatus he was personally of the opinion that a certain liberty should be left.

Prof. **Heyn** did not at, the time being, consider that the results of tests could be rendered comparable unless they agreed as to the apparatus. The object which Mr. Charpy aimed at might be

realised in the following way. There were undoubtedly excellent apparatus well suited for impact tests; some works possessed such apparatus and wished to make further use of them. The use of these apparatus would not involve any difficulties. It would, however, be necessary to enquire into the relations existing between the results obtained with those machines on standard bars, and the results obtained with the standard machine. That proposal would pave the way to an understanding, and they might, without fixing one type of apparatus, obtain results which could be expressed in a common language.

Unless they decided on a standard impact testing machine and reduced the results obtained with other machines to the standard figures, a great mass of material would be brought together that would certainly not be comparable. Prof. Heyn referred to the publication of British tests which were made with different apparatus and which had given very different results. These facts could not be ignored. They might decide upon the relations which ought to exist between the standard impact testing machine and other machines, without limiting the free selection of a machine and while preserving the comparability of the results.

Mr. **Charpy** remarked smilingly that it would be ungrateful on his part to decline the homage paid to his machine. But the decision of the Congress should not lose sight of the fact, that a better machine might be found, nor refuse recognition of a better machine already in existence, as, for instance, that described by Prof. Schüle.

Prof. **Heyn** explained that his remarks were not exclusively to be interpreted as in favour of the Charpy hammer. Every correctly constructed apparatus might make a standard machine. It was immaterial to him which type would be selected; but he considered that it was necessary to decide on some type as the standard. If the future should teach them, that the construction of the machine did not exercise any influence, they might dispense with adhering to some particular standard. But they should not a priori presume, that this influence did not count.

Prof. H. **Le Chatelier** reminded the Section that the question of impact tests had been on the Agenda of the International Association for the last eight years. The Congresses both at Budapest and at Brussels had deliberated on reports without arriving at any

decision. They should not again indefinitely adjourn the questions, not those, at least, upon which they were agreed. The measure to be taken was simple. They were in accord as to the test bars; they were not in accord as to the machine. It would hence be logical not to pass at present any resolution regarding this latter question, but to refer it back to the Committee.

Mr. **A. Greiner** believed that the motion proposed by Prof. Heyn had not quite been understood by Mr. Charpy. The motion in fact fell in with the wishes of Mr. Charpy. Every establishment would be in a position to make use of an impact testing machine of its own choice. In order to eliminate all doubts as to the comparability of the results, however, the data should be reduced to results which would, under the same conditions, have been obtained with the Charpy machine.

Mr. H. **Le Chatelier** pointed out that the comparison of results obtained with different machines and with the standard Charpy machine would involve difficulties. There were, moreover, three sizes of the Charpy machine; which was one to be selected? The comparison ot the machines themselves implied considerable difficulties. They could not simultaneously break the same bar on two different machines. That needed two different bars, and there would often be as much difference between the bars as between the machines. And if they adopted some standard machine to-day, would they not call forth the protests of all the constructors of other machines? Would not the Congress be regarded as the enemy of progress? For these reasons, the speaker proposed that the Congress should confine itself to the first part of the resolution (the test bar) and should refer the second part (the machine) to the competent committee which would have to deliberate on all the other questions.

(Luncheon Interval.)

Mr. **G. Charpy** concurred in the views expressed by Mr. Le Chatelier and submitted finally the following resolution, which he had drawn up in conjunction with Professors Heyn and Le Chatelier:

A. In order to facilitate the comparison of results of impact bending tests on notched bars the Congress recommends the observation of the following rules, unless circumstances prevent.

1. The notched bar impact test permits the determination of the specific work of rupture or resilience referred to the sq. cm. of the notched section.

2. a) The bars cut to sufficient length have the following dimensions: $30 \times 30 \times 160$ mm. They are notched to a depth of 15 mm. The bottom of the notch bar is cylindrical of 2 mm. radius.

b) For rolled materials such as plates, the bars have the same thickness as the plate, the skin being preserved, and a width of 30 mm. They are notched to a depth of 15 mm. The notch is perpendicular to the surface of rolling and has a cylindrical bottom of a radius of 2 mm.

c) For pieces which do not permit the use of bars 30×30 mm. in section the bars are 10×10 mm. They are notched to a depth of 5 mm. The bottom of the notch is cylindrical with a radius of $^2/_3$ mm.

d) The size of the bars used is always to be recorded.

3. In the combined bending and impact tests the impact of the tup is applied at the centre of the bar, on the opposite side to the notch, the tup having a knife edge rounded to a radius of 2 mm. They rest on knife edges spaced 120 mm. apart in the case of types a and b, and 40 mm. in the case of type c.

4. The rupture of the bar shall be effected by a single blow by means of an apparatus which enables the work done in fracture to be measured.

5. The temperature should be as nearly as possible between 15 and 25^0 C. and shall in all cases be noted with the results of the tests.

B. The Congress recommends that a Committee be appointed to collate all the results which permit the establishment of relations between the properties, brought out by the tests, and the behaviour of the pieces in service, and that this Committee also study the comparison of the various apparatus.

The resolution was carried.

The Section proceeded to the discussion of report III_8:

The Definition of Resilience in Impact Tests.

Mr. **L. Révillon** (Paris) presented a brief summary of his report, copies of which were in the hands of the members. He commented

on the results of the numerous tests, he had made with a view of determining the relations existing between the results of impact tests performed on different test bars. The data gained by these tests, which already constituted an important basis for the work of the committee that had been appointed on the proposal of Mr. Charpy, seemed to demonstrate that it was possible to compare results obtained by impact tests on bars of different dimensions, and this by referring the data found to the unit of the whole (unnotched) cross-section. It was, however, necessary always to experiment with test bars of the same type, enlarged or reduced in a uniform ratio, and to reduce the distance between the supports in the same ratio at the same time.

So far as these experiments admitted of generalisation, they would enable engineers to adopt a standard test bar and to employ in all impact testing machines appropriate bars which would, both as regards the dimensions and the distance between the supports, bear a definite ratio to the standard test bar. Thus the comparability of the results and the unification of the methods of testing would be secured.

Impact Tests at Various Temperatures (III_4).

Prof. **L. Guillet** (Paris) said that his printed report formed a continuation to the memoir presented by Mr. Charpy to the Brussels Congress. The most important conclusion which the speaker and Mr. Révillon had drawn from their experiments was, that steels displayed in impact tests a distinct minimum of the work done in fracture almost exactly at 475° C. This temperature of the minimum of resilience was independent of the carbon percentage. Mr. A. Le Chatelier, when informed of this observation by Guillet and Révillon, had remarked, that they would probably displace the temperature of the minimum if they changed the velocity of the shock. They had consequently conducted further experiments; these experiments were not embodied in the report, but had been published in the "Revue de Métallurgie". They proved that in spite of the fact that the velocity of the impact had been varied in fairly large limits, no change had been observed in the temperature of 475° C., corresponding to the minimum.

The speaker then communicated the results of quite recent impact test experiments on special steels. The curves, he exhibited,

were the outcome of long-continued researches, and he had, in conjunction with Mr. Révillon, arrived at the conclusion that there existed an intimate relation between the resistance to shock in the hot and the structure of the steels, notably of nickel steels. It had clearly been established that nickel steels of pearlitic structure gave a curve for the variation of brittleness with temperature similar to that of ordinary steels, which were also known to be pearlitic. The martensitic steels yielded an absolutely continuous fragility curve, without maximum or minimum. Thus the resistance to shock increased at the same time as the temparature. Finally, the polyhedric steels marked a maximum at 100° C., and further a minimum at 460° C., like the pearlitic steels. The author added that the curve of the martensitic steels had been obtained at a temperature which was not high. When these steels were heated to a notably higher temperature and for a sufficient period to make them assume the polyhedric state, totally different results were obtained in accordance with the structure which the steel assumed (polyhedric or martensitic).

Mr. Guillet expressed his intention of extending this research to diverse special steels. He hoped to present to the next Congress a report on tension and compression tests in the hot, questions which seemed to be of particular importance, considering that metals had often to perform their duty at high temperatures, for example in steam turbines.[1])

Impact Tensile Tests.

Mr. **Breuil** (Paris) presented his report on:

Impact Tensile Tests (III_5).

[1]) Engineer-in-Chief Bartel, of Budapest, prevented from attending in the last moment, communicated in writing several remarks upon the report of Messrs. Guillet and Révillon. Researches incurring the blue heat brittleness (A. Martens, Mitteilungen, Berlin 1890, page 159) appeared to him particularly desirable. Scientific experiments should elucidate why it was detrimental to work ingot-iron at certain temperatures. His own (Bartel's) experiments had convinced him that the dangerous temperature ranged from 0° to 500° C for diverse kinds of ingot-iron, and that certain chemical elements seemed to influence this blue heat brittleness. He would suggest to Guillet and Révillon to investigate this point and to test metals worked at blue heat on impact machines in the cold. The chemical analyses should determine N, in addition to P and S.

Mr. **Welikhoff** (Moscow) presented his

Note on the Rupture of Standard Cylindrical Test Rods by Longitudinal Impact (III_8).

Numerous experiments, conducted at the Imperial College for Engineers, at Moscow, Mr. Welikhoff stated, proved that these tests deserved the highest attention. They could easily be carried out with the aid of the method which he proposed. They yielded data which were in accord with static tests and might even replace the latter, and they further permitted of determining the work done in fracture with accuracy. He recommended that the Committee charged with examining the impact tests and to unify their methods, should also enquire into longitudinal impact tests (Acclamation).

The **Chairman** then invited, His Exellency Dr. **Exner** (Vienna) to report:

On the International Statutory Regulation of Technical Testing.

"If the same units of measures and weights were legally established in all the states of the world, an ideal state of affairs would result. Notwithstanding the very general use of the metric system, the resistance offered by Great Britain to the adoption of this system still places us very far from this desirable ideal. On the other hand, the fact should not be lost sight of that it has required decades of efforts and of preparatory work to accomplish the progress already made.

The International Association for the Testing of Materials, now holding its V^th^ Congress in Copenhagen, has for the last 25 years been endeavouring to attain such an object, to arrive at a wholly homogeneous terminology, to secure the unification of methods of testing and to obtain that equal value be given to the reports issued by the various authorised establishments. The organisation of our International Association gives evidence of a very great development; from small beginnings, (it was started by a very limited number of specialists,) it has grown to be a powerful institution, comprising several hundred scientists.

Since the Zürich Congress of 1895 and partly with my collaboration, the programme of investigating the various structural materials has been extended so as to include numerous other classes of raw materials and manufactured products.

There is no restriction to the scope of our work and no need whatever to limit it to the testing of materials; on the contrary it may be made to embrace the whole range of methods of technical research.

Both the testing of materials and other, more or less closely allied, technical research work gain in practical importance when an international agreement is arrived at concerning them. Among such researches may be mentioned, for instance, the goldassay in articles made of alloys, the testing of barrels for small arms, the technical and bacteriological examinations of foodstuffs, and so forth.

The extension of the programme with a view to increase the efficiency and the importance of the Association may take place in various directions as to which the questions which we have been discussing afford a few indications.

I. Methods of testing materials.

Under this heading the following points may be considered:

a) The methods hitherto used, or proposed, may be investigated in regard to their reliability and their accuracy, or

b) new methods may be tried under manifold conditions and reported upon (Metallography: I_1, I_2, I_3; Hardness testing: II_1, II_2, II_3 etc.) can be followed, or again

c) recognised methods for meeting special purposes can be mproved either with reference to the proposed use of the material (conditions of supply) or with regard to questions of processes of treatment, production, manufacture and so forth.

In the above, the problem resolves itself into a deductive utilisation of material testing, either "pro futuro" or "pro preterito".

All the points under this heading concern the greater development of the science of testing materials by perfecting the methods themselves or by improving the machines, apparatus, instruments used in connection therewith.

II. Extension of the Range covered by the Work.

The present programme, besides two distinct sections: A. Metals, B. Cement, Stone and Concrete, comprises a third, indefinite section, dealing with Sundries and including Wood, Indiarubber, Oils, Paints, Rust preventives, Asphalt, Paper, Tissues, Belting etc.

a) This division is not a satisfactory one, since, for example, materials for reinforced concrete structures can hardly be separated from the first section dealing with metals; it is, further, insufficient and decidedly unscientific. The section covering "Sundries" should be divided up into technologically well-defined sub-sections. And at this point it may well be asked whether, instead of grouping the subjects according to the materials dealt with, it would not be preferable to select a grouping according to the nature of the testing methods followed.

An attempt could at least be made to adopt, simultaneously with that now selected,

b) a grouping according to the methods of research or according to the scientific fields from which they have been chosen. The new groups might fall under the headings: Microscopy, Metallography, Bacteriology, Engineering, Physical Technics, Technological Mechanics, Chemistry, Electrotechnics, Electrochemistry, etc.

It is perfectly clear that, were such a grouping selected, the sphere of material testing would considerably be widened; it might become so extensive as to cover, besides structural and construction work, the whole domains of engineering, industry and trade.

III. Utilisation of the Expedients used in Engineering for Industrial Problems.

International Conferences have enabled our Association for Testing Materials to spread the news of novel inventions and of progress and to pave the way for a unification of technical language as well for reciprocity in the recognition of results achieved. There is no reason, why the same success should not be attained; by the same intermediation, with respect to the testing of motors, power engines and tool-making engines, and to the technical tests by means of which success of the processes applied is secured in various industrial branches.

Our chief aim in industry and trade, not less than in engineering, is to secure a final result which will realise our original intentions to the fullest extent. Without wishing to dispute the justification, and even the indispensability of specialisation in research, or to depreciate its value, we most concede that we can no longer continue to consider the properties of materials

apart from their connection with the methods of treatment and the technical processes applied — if we aspire after progress in its totality.

The latest phase in manufacture and in the means of locomotion is represented by automobilism and aerial navigation. Empirical methods have in that field, certainly yielded astonishing results, and technical researches have already solved a number of isolated problems appertaining to this comparatively new industry; but the testing of materials has been neglected to an incomprehensible extent. More progress would have been achieved, had this been brought to act at the right moment. Further, the fact that the testing of materials has not been included in the systematic trials made with the different models and expedients, has tended to cast doubts upon the whole matter and upon the results obtained, considered from technical and economical standpoints.

It is precisely the remarkable development taken by the methods, for testing materials, the importance of which is now generally recognised, which calls for the extension of technical testing to all branches of production and locomotion.

The development of material testing, of industrial laboratories, and so forth, has sufficiently paved the way for the extension of technical research over the whole range of production and manufacture; all that has been accomplished so far may be considered as preliminary work, as efforts, however, which have matured, and the science of testing is now able to play in the world's economics the part which belongs to it. If this train of thought be accurate, then duties in regard to supervision and legislation fall to the industrial nations, the fulfilment of which duties can no longer be considered solely from the national point of view. We have to remember our duty to international progress.

As an illustration of the foregoing may be mentioned the testing in the automobile and aeroplane trades[1]) etc. of to-day, and

[1]) With reference to the automobile industry the speaker pointed out that there were in various countries, but more especially in France, where this industry had its birth, a number of testing laboratories which were:

either exclusively private laboratories,

or public institutions.

The former had been put down by the manufacturers for their own use, and the latter were due to public bodies or to the State. Among the private labo-

the commencements made in Austria to promote tests and researches by legislative means and by State supervision.

The Chairman thanked Prof. **Exner** for his most interesting and far-reaching suggestions which, as the lively applause sufficiently indicated, had appealed to the Section.

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ratories there were some which were not closed to outsiders, but were placed at the service of the industry generally. A praiseworthy example of one of these was the testing laboratory of Messrs. de Dion-Bouton which had earned a well-deserved reputation in the matter of material testing. Among the latter institutions were the laboratories of the Automobile-Club of France and of the American and Spanish Automobile clubs; as an example of a Government institution, there was the Conservatoire des Arts et Métiers, in Paris.

The work of these institutions might be divided into the following five groups, the one or the other of which received particular attention by the one or the other institution referred to:

1. The testing of materials,
2. The organisation of competition for contracts,
3. Special researches for manufacturers,
4. Studies of general interest,
5. Collaboration for the preparation of programmes and for the supervision of trials.

Much successful work had been done under section 2 in regard to fuel, gas, gasolene, petrol, alcohol, mineral oil, etc.; to silencers; to automatic starting devices meters, etc.

The special research work under heading 3 was the most difficult item on the programme of the laboratory, and for this, special devices and installations were required. In private laboratories, the problem resolved itself mostly into the testing of distinct types; and brake tests of motors separately or of whole cars were the most usual. But there were, besides, other special problems to be dealt with such as experiments with carburettors, ignition devices, silencers, cooling devices, and so forth.

As regards the studies of general interest, the work of a laboratory dealing with automobile technics could be carried out in co-operation with that of a chemical or of a physical testing laboratory.

A large series of most interesting researches had already been made in the laboratory of the Automobile-Club of France, such as, for example, on the Influence of Heat upon the Ignition; the Strength of the Springs for Automatic Valves; the Effect of the Cooling of Exhaust Gases on the Efficiency of a Motor; the Design of an Alcohol Carburettor. At the present time this laboratory was dealing with the Effect of Skidding as limiting tractive Effort.

The French Automobile Industry owed much in regard to testing, to Levassoir, to Messrs. Perissé, Lumet and other leading specialists, whom death unfortunately had removed at an early age.

On the proposal of Prof. Le Chatelier he then re-opened the discussion on

Uniform Nomenclature of Iron and Steel.

Prof. H. Le Chatelier (Paris) referred again to the designations proposed in their report by Messrs. Howe and Sauveur. In conjunction with the metallographers present, Messrs. Charpy, Guillet, Heyn, Rosenhain and Stead, he had drawn up a table of definitions of generally recognised constituents and he begged to submit this table to the Congress.

They had not included in this table the constituents troostite and sorbite, cencerning which the scientific researches were not yet concluded.

The definitions submitted by Prof. Le Chatelier were then passed in the following terms:

The microscopical constituents of steel are divided into chemically homogeneous constituents "metarals" and into chemically heterogeneous constituents "agregates". These microscopical constituents, classified in the order of their increasing complication, are as follows:

Ferrite. α iron, containing in solution, in the commercial iron and steels, very low percentages of other elements, and containing always less than 0.05 of carbon.

Graphite. A variety of carbon which is identical with the graphite of mineralogists, characterised by a density of 2.25 and capable of yielding graphitic oxide under the action of suitable oxidising agents.

Cementite. A carbide of iron represented by Fe_3C.

Austenite. A solid solution of carbon and iron in the γ state, normally stable above the zone of the critical temperatures for steel. In some special cases this may persist at ordinary temperatures, and the steel is then characterised by the low degree of its magnetic permeability. (Ferro-nickel, manganese steel.)

These four constituents are chemically homogeneous.

Pearlite. An "agregate", constituted by the eutectoid proceeding from the normal separation into the ferrite and cementite of the austenite cooled down slowly below the zone of the critical temperatures for steel. It contains on an average approximately 0.9% of carbon.

Martensite. A "metaral", a solid solution of carbon and iron. It is not normally stable at any temperature, and it can be maintained as a metastable phase only at low temperatures. With a similar composition it is distinguished from austenite by its magnetic permeability and its greater hardness. It is obtained by cooling down steel from temperatures above that of the critical zone, rapidly enough to prevent the splitting up of the austenite with a consequent production of pearlite, but at the same time, slowly enough to maintain the austenite unaltered.

Characteristic specimens of martensite are obtained, e. g., by quenching in cold water from 800^0 C. (1472^0 F.) bars of 1 cm square of eutectoid steel, i. e. steel containing about $0.9^0/_0$ of carbon.

Osmondite, the homogeneity or heterogeneity of which is still under discussion, marks an intermediate stage in the return of martensite to the pearlite phase. It is more stable than martensite at ordinary temperatures. It is considered to be a constituent proper owing to the existence of a discontinuity in the variation of certain properties of the metal during transformation from one extreme phase to the other. It is characterised by possessing a maximum solubility in acids and by a maximum coloration under the action of acid metallographical reagents.

It can be obtained very definitely by annealing at 400^0 C. (752^0 F.) the martensite of eutectoid steel, i. e. steel containing about $0.9^0/_0$ of carbon.

Automatically Recording Impact Testing Machine.

Prince **Gargarin** (St. Peterburg) reminded members that he had presented a report on his registering machine to the Brussels Congress. He showed diagrams illustrating the results obtained which brought out the relations between stress and strain very clearly.

He asked members to make use of his machine and to communicate to him the results of their experiments.

Internal Strains.

On this problem the following reports had been presented:

On the Principles of Technological Mechanics. By Dr. Techn. Paul Ludwik, Vienna ($VIII_8$).

Internal Friction in Loaded Materials. By Prof. G. H. Gulliver, B. Sc., Edinburgh ($VIII_9$).

On Irregular Strains due to Non-homogeneity of Materials. By Dr. Techn. A. Leon, Vienna ($VIII_{10}$).

*) Connection between the Permanent Sets caused by Traction and Compression. By Dr. Ing. Wilhelm Misángyi, Budapest ($VIII_{11}$).

*) Tenacity and Malleability. By Dr. Ing. Wilhelm Misángyi, Budapest ($VIII_{12}$).

Prof. **A. Mesnager** (Paris) who had undertaken to present the general report on the important problem of internal strains, regretted that the advanced time did not permit him to deal at length with the several memoirs presented. He pointed out, however, that the definitions adopted by the various authors diverged so strongly from one another, that it was impossible to come to an understanding. Thus, in Hungary, the terms ductility and malleability were not used for the properties to which they were applied in France and Germany. A material was characterised in Hungary as not having any tenacity, while it would elsewhere pass as having great tenacity. The word "strength" was sometimes referred to the unit area of cross-section, sometimes to the total strength. It should not be impossible to arrive at an agreement in the same manner as in electrical science where "resistance" was distinguished from "resistivity" and referred, the one to the total resistance, the other to the unit resistance. Prof. Mesnager proposed to appoint a Committee, with the object of settling these terms.

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*) As it was impossible to invite discussion of these reports, a few suggestions should here be mentioned which Engineer-in-Chief Bartel, of Budapest, communicated in writing:

1. Experiments should be made with Durana metal and other materials, in which the tension diagram showed a very long horizontal curve, and which therefore underwent a great part of their extension at constant maximum load. In such materials Prof. Stribeck, and also he himself had observed, that the reduction of the cross-section retained the characteristics of the original shape of the rod during the period of tenacity (before the beginning of the contraction); this was in contradiction to Misángyi's statement.

2. Study of the relation between working in the cold and the deformation and change in the tenacity resulting from it. According to Mr. Bartel, the state of maximum tenacity would coincide with the state of maximum malleability.

The Chairman, Director **O. Busse**, regretted to have to ask the Section to refrain from a discussion of these reports, in consideration of the advanced hour. He cordially thanked the authors for their work. He was also anxious once more to express his thanks to the investigators present for their active participation in the discussions, which had proved so valuable to the development of metal testing. Particular thanks were due to the gentlemen who had so well deserved of the Congress by acting as interpreters, Professor Weiss, Mr. G. C. Lloyd and Dr. W. Rosenhain, and they were likewise indebted to the Secretary General, Mr. Reitler, for his assistance (Applause).

The **Chairman** then adjourned the meeting, expressing the hope that they would all meet again at the next Congress.

Mr. **Greiner** (Seraing) rose to thank the Chairmann, Mr. Busse, for the great services he had rendered to them. The conscientious discharge of his honorary duties during the three days of continuous strain, that he had presided over the Section, entitled him to the cordial gratitude of all the members. Mr. Greiner was happy to take this opportunity for expressing their gratitude to their Chairman (General, long-continued applause).

The meeting finally adjourned at 3 p. m.

Proceedings of Section B.

First Meeting, Wednesday, Sept. 8th, 1909.

Opening of the Meeting at 9·30 a. m.

Prof. **Schüle** opened the meeting and communicated the names of the honorary presidents and honorary secretaries, as also those of the secretaries, and requested Captain Grut of the Engineer Corps to accept the presidency.

Capt. **Grut** expressed his thanks for the honour done to him and invited the honorary presidents to take their seats on the platform; further he requested the honorary secretaries to give him their assistance in interpreting the discussion. Finally he asked the speakers to express themselves as briefly as possible, since all the 32 reports sent in, which were now in the hands of the members, would have to be dealt with in three sittings.

He first invited discussion on Report No. $IX/_1$ on

Reinforced Concrete.

Prof. **F. Schüle** (Zürich), President of the Committee on Reinforced Concrete, observed that, partly by reason of the shortness of the time at their disposal and partly on account of the considerable extent of the subject, the labours of the committee had only been of a preliminary nature. The committee had endeavoured

1. to determine the state of advancement attained by experimental research in the different countries;

2. to determine the state of advancement of the measures of control taken to ensure good work;

3. to establish a uniform method of notation for the data and results of the ordinary calculations;

4. to establish a systematic method of procedure for giving expression to the arrangement and results of testing experiments.

The reports distributed show the work done in Germany, Denmark, Italy, and Switzerland. Further Prof. Talbot had pre-

sented — too late for printing — a report in regard to the United States, which was distributed at the section meeting.

It was desirable that the labours begun be continued and that the committee be kept informed on the results obtained in the different countries, so that the repetition of work already done in different places might be avoided.

As might be seen from the reports, the investigation of the subject of reinforced concrete was conducted by the help of prisms and cubes — generally the latter — which were prepared in the workshop and then submitted to crushing tests. Opinions differed very much as to the value of this method of testing, and it would be very desirable that a decision should be made as to the best manner of preparing these test-samples.

The question of a uniform nomenclature for reinforced concrete had been prepared by a sub-committee in such a manner that an agreement of the continental countries had been brought about on the basis of the method suggested by Culmann 10 years ago.

Small Latin characters for lengths and quantities of the first degree;

large Latin characters for quantities of a higher degree, and small Greek characters for coefficients and factors of the degree zero.

The members of the English Concrete Institute had adopted this principle, but had proposed notations that were to some extent different.

It was to be hoped that it would prove possible to bring the two lists of notations better into harmony with each other; they would then be published. It would denote a great step forward if the number of letters representing each particular conception were confined to two, corresponding with the languages employed. In this way the study and the application of the results of investigation would be considerably facilitated.

Finally, it would be desirable to recapitulate the arrangements and results of the tests in a uniform summary manner; this was a piece of work which had not yet been taken in hand, but which would greatly facilitate the study and the comparison of publications relating to reinforced concrete.

For the rest, the committee would, in regard to the work done, give due consideration to the wishes expressed in the section.

Two very important questions had been discussed by the members of the committee. These related to

accidents in connection with reinforced concrete, dealt with by the report of Mr. von Emperger, and

the experimental investigation of completed structures dealt with in the report of M. Rabut.

Finally Prof. Schüle mentioned that the labours of the Swiss committee on reinforced concrete had rendered possible the laying down of new Swiss rules, a number of copies of which he distributed.

Prof. **N. Belelubsky** (St. Petersburg) reported in a few words on the tests and scientific laboratory work and on researches made by individual investigators in Russia; these had to a notable degree forwarded the progress of reinforced concrete constructions. He drews special attention to the various tests made in 1890 under the direction of the mechanical laboratory of the Imperial Russian Road-Building Institute in Préobrojensky Square, St. Petersburg. These tests had contributed to a notable extent to the establishment of public confidence in the safety of buildings in reinforced concrete. The speaker recalled the special experiments of Abramoff and Nékrassoff, of Prince Kudascheff, and others, and stated the instance that regulations had quite recently been laid down by the Congress Office of the Russian Cement Engineers, with the co-operation of Messrs. Drujinine, Bojuslawsky, and other investigators. These rules for reinforced concrete constructions had been approved by the XII. Congress and are at present under consideration by the Ministry of Roadway Construction. The speaker would shortly present a report for publication in the "Communications".

Prof. **B. Kirsch** (Vienna) observed that experiments on reinforced concrete were in progress in Austria also. These extended to columns, blocks, and slabs, and to different kinds of reinforcement. A report on the results obtained would be presented to the members of the Association at a later period.

M. **A. Segré** (Rome) in the name of the General Management of the Italian State Railways presented a number of reports the object of which was to show how construction in reinforced con-

crete had developded since 1900 in Italy. He handed over to the President the report presented to the Washington Congress by the Italian State Railways and the report published in 1906 by the Service de l'entretien des chemins de fer de l'Etat Italien (Maintenance of Way Department on the Italian State Railways) on various types of reinforced concrete structure; finally he presented a resumé of the more important labours of the "Department for the Construction of new lines on the Italian State Railways". He added that the cements and reinforcements used in railway works were tested in the State railway laboratory before their use was sanctioned. At the desire of the engineers in charge of the works, the materials brought to the place of construction were likewise tested and occasionally also, for structures of importance, the mortar. As regards reinforced concrete constructions, the Experimental Institute in Rome made a general inspection of the production of Portland cement in Italy every six months. The administration never restricted the choice of the contractors to any particular source of supply, but reserved to itself the right of testing the materials.

Mr. **A. Hüser** (Oberkassel-Siegkreis) reported that in Germany the well known "Rules for the carrying out of reinforced concrete constructions in buildings, of May 24th, 1907", emanating from the Prussian Ministry of Public Works and the "Rules for the Preparation, carrying out, and testing of reinforced concrete structures of the Union of German Architects and Engineering Institutions and the German Concrete Association" had meanwhile been simultaneously published. There was now in existence a "German Committee for Reinforced Concrete" consisting of public functionaries representing the ministries of the different confederated states and of the constructive industries represented by the German Concrete Association. This German "Committee on Reinforced Concrete" was at present conducting very extensive experiments on mortars and on reinforced concrete in order to obtain experience on which to base rules for the construction of buildings in this material. Since the interest here taken in these rules centres, chiefly in the ones relating to reinforced concrete, Mr. Hüser communicated the programme of these research-works in general terms. Further he called attention to a list to be distributed in the form of a separate pamphlet, containing the

results of the experiments made on reinforced concrete in the large establishments for the testing of materials.

Mr. **M. Bürstenbinder** (Hamburg) called attention to the comparative experiments which he had made with test-sample cubes of 30 cm square and with sample beams made in accordance with the Danish rules. He thanked Engineer Christiani for help which he had given him. He drew attention to the very widely diverging results of the two series of experiments, and did not consider either of them to be satisfactory. For instance, in regard to the cubes, he believed that their length side of, 30 cm, might have been decreased. He laid stress on the necessity of instituting a uniform system of testing.

Mr. **R. Christiani** (Copenhagen) had, within the last few years, made more than 200 tests on small beams of reinforced concrete. These tests were very simple, and they gave results of a very uniform kind. If these latter were so different from those given by the cubes, the reason was that the beams were only small bodies which could set in a few minutes. On the other hand, the much larger cubes attained very different degree of hardness. The cubes were also rammed and are thus produced in a much drier state than the beams.

Prof. **F. Schüle** gave still another explanation for the discrepancy in the results given by the two processes, which lay in the reinforcement. The difference was due to the circumstance that the iron in the sample beams was strained beyond its elastic limit, the concrete playing only a secondary part.

Mr. **A. Hüser** (Oberkassel-Siegkreis), recommended that the dimensions of the cubes be proportioned to those of the beams in such a manner that the drying of the two sets of bodies be the same. For the comparison with small beams, small cubes should be chosen; for that with large ones, such as those found in buildings, cubes of 30 cm length of side.

Prof. **D. v. Nagy** (Budapest) called attention to the tests made by the Hungarian Engineers' Association, to be discussed later. He traced the most important influence exercised on theresults of the tests to the proportion of water contained in the samples Samples differing in shape ought to give the same results if they contained the same proportion of water.

Mr. **R. Christiani** was likewise of opinion that the differences were partly due to the proportion of water. The small beams were perfectly homogeneous at the end of eight days, but not so the cubes.

Mr. **M. Bürstenbinder** said the tests under discussion were made on the building-ground. It was not possible, therefore, exactly to determine the quantity of water.

The **President** proposed that a vote of thanks be accorded to the committee, and that they be invited to continue their labours on the lines indicated by Prof. Schüle.

Mr. E. O. **Sachs** (London) expressed the wish that the committee work out a resumé of the work done in the different countries in connection with reinforced concrete, and submited a motion in which the view was expressed, that the governments should afford them financial assistance. The section adopted the motion which took the following form: —

"The Congress thanks ed Committee 41 for the work already done invites them to proceed upon the plan described by Professor Schüle, and expresses the wish that the Committee be financially supported by the competent institutions and authorities."

Report IX_2. Reinforced Concrete Structures. Measure of the Deformation of Structures under Service Conditions.

Mr. **C. Rabut** (Paris) resumed his report and showed the necessity of supplementing the results of laboratory researches by means of measurements made on existing structures. He asked that the Congress be invited to give its moral support to the investigations by declaring such experiments to be useful and to further the end in view, and, in certain cases where such action may be necessary, by its taking steps to obtain the approbation and effective co-operation of competent authorities.

In relation to Mr. von Emperger's report on

Casualities in Reinforced Concrete Building (IX_3).

Mr. **E. Maynard** (St. Nazaire) made the following observations:

In his report Mr. v. Emperger had pointed out the various causes which lead to accidents in reinforced concrete structures. In particular the weakness of a structure must often be referred

to the defective preparation of the concrete. One important cause had, however, been forgotten, and that was the covering layer of cement-mortar 2 or 3 inches in thickness, which was often applied to the concrete. The coefficient of contraction of this layer being higher than that of reinforced concrete, it broke in the process of contraction and dragged the concrete with it, which was thus itself fractured. This circumstance had often been noticed in the case of beam coverings and in reservoirs, the walls of which had thus been caused to leak. This showed itself especially when the covering and the concrete itself had been subjected to a high temperature too soon after their production. The manufacturer should rest content with the removal of the inequalities of the concrete with a mortar of 800 to 1000 kgs. of cement to the cub. m. of sand, or, where the covering cannot be dispensed with, the thickness should be limited to from 5 to 10 mm.

The **President** observed that Prof. Kirsch (Vienna) had submitted a report on the

Influence of repeated Loading upon the Adhesion between Concrete and Iron of bright and of rusty surfaces (IX_4).

No one wishing to speak, he initiated a discussion on the report of Mr. Nekrassow (St. Petersburg) on

The Influence of Small-Sectioned Transverse Ties on the Strength of Concrete. System of Free Ties (IX_5).

Mr. **V. Nekrassow** (St. Petersburg) gave a short resumé of his report accompanied by a number of pictures thrown upon the screen, and moved the adoption of the resolution embodied in it, which recommended this system.

Mr. **E. Maynard** (St. Nazaire) had in 1902 already made tests with uncovered pieces of iron for strengthening concrete and had obtained good results with them.

Mr. **C. Rabut** (Paris) said that strengthenings of the kind mentioned had already been applied in practice for several years, principally for columns, but also for beams, vaultings, and masonry. Very light and yet reliable structures had thereby been obtained. The merit of this belonged to the engineers Messr. Harel and La Noë.

The **President** thanked Mr. Nekrassow for his interesting paper, but was sorry to be unable to move the resolution desired by him, because the Congress could not on principle, shew preference for one particular system of reinforced concrete out of the many in existence.

(Adjournment for luncheon.)

The **President** opened the discussions on

Cement in Sea Water.

Mr. **Colomb** (Paris) presented the report of Mr. Bied on

"Experiments on the Decomposition of Mortars by Sulphate Waters" (XI_1),

and especially directed attention to the illustrations of the test samples.

Mr. **W. Czarnomski** (St. Petersburg) spoke on his report.

"On the Condition of the Cement Blocks in some of the Russian Ports in the Black and Caspian Seas" (XI_2).

He thanked the Danish engineer, Mr. Poulsen, for his valuable work on the destruction of cements in sea water. The experiences of the speaker differed from those of Mr. Poulsen in so far that the waters of the Black and Caspian Seas never show a lower temperature than 5^0 C. The destruction of Portland cement or concrete occurs principally in two forms: — 1. Superficial deterioration due to the influence of the blows of the waves, that is to say, principally to mechanical action, and 2. Interior deterioration, principally of a chemical nature.

Prof. **M. Gary** (Gr.-Lichterfelde), called attention to the second report on the behaviour of hydraulic cements in sea water, presented by the Royal Testing Laboratory in Gr.-Lichterfelde, which had been distributed separately to the members of the section. The first report appeared so long ago as 1900. For these tests, use was made both of waterproof and of porous mixtures. The experiments with cement-concrete were compared with those made with trass concrete. The test samples were kept both in fresh and in sea water. They were also subjected to natural conditions, which are in existence on the north west coast of Germany. The speaker did not wish to go too much into detail, but only to

establish what he considered to be the two principal results of these tests, viz. 1. that the addition of trass to the puzzolanas is favourable to the durability of cement, and 2. — what appeared to him to be the main point — that, for the durability of the cement. it is very necessary that waterproof mixtures be made use of. The experiments had already extended over a period of more than 5 years. Since the test samples were built into the structures in an alternate sucession and all the mixtures were thus subjected to identical conditions of stress, it had been possible to determine with certainty that a well-made cement-concrete can withstand sea water for many years. It had not been possible to establish the occurrence of disintegrations from within. He attributed this in the main to the circumstance, that the samples were very carefully prepared and hardened in air for a sufficient length of time. The observation had been made that sample-blocks which were immersed in sea water as soon as manufactured had a much smaller power of resistance than those which, during a year's exposure to the air, had become sufficiently hardened. He observed also, that these experiments also included a number made with lime-trass mortars.

Dr. ing. Rud. **Dyckerhoff** (Amöneburg) wished to supplement the communications of Mr. Gary by drawing attention to a series of tests, relating to the manner in which Portland cement behaves in sea water, made during a period of two years on Sylt (North Sea) by the Association of German Makers of Portland Cement. The occasion for these tests was the rule laid down by the Argentine Republic in accordance with which cement for marine work must not contain more than 1 per cent of sulphuric acid. Since, according to the experience of the Association, a percentage of sulphuric acid higher than this, within certain limits of course, does not act detrimentally, the following tests with two kinds of Portland cement were made in order to solve the question.

Cement A was a Portland cement which is applied to all sorts of purposes including those of marine structures. Cement B was a Portland cement of a kind that is specially supplied for marine structures. The former has a percentage of sulphuric acid of 1.28 per cent, the latter a percentage of 0.56 per cent. In the cases of both cements the percentage of sulphuric acid was raised to 2.5 by suitable additions of plaster of Paris.

Preliminary Communication of the Results of the Royal Laboratory for the Testing of Materials.

Tests made on Sylt on two Portland Cements with different percentages of Sulphuric Acid hardened in fresh water, in sea water, and in air. Resistances to compression in kgs./cm² shown by cubes of 50 cm² in surface.

Mixing Proportions by weight	1 Cement + 2 Sand			1 Cement + 4 Sand			1 Cement + 2 Sand			1 Cement + 4 Sand			
Immersion up till time of test	Fresh Water	Sea Water	Open Air	Fresh Water	Sea Water	Open Air	Fresh Water	Sea Water	Open Air	Fresh Water	Sea Water	Open Air	
Kind of Cement	Cement A unmixed: Percentage of Sulphuric Acid 1·28						Cement A with 2·77% Addition of Raw Plaster of Paris: Percentage of sulphuric Acid 2·5						
Age 28 days	613	573	649	268	241	291	616	588	730	348	295	388	kg/cm²
„ 1 year	656	620	855	259	251	405	875	716	821	348	236	393	„
Kind of Cement	Cement B unmixed: Percentage of Sulphuric Acid 0·56						Cement B with 4·36% Addition of Raw Plaster of Paris: Percentage of Sulphuric Acid 2·5						
Age 28 days	257	278	302	109	113	143	288	254	345	112	101	143	kg/cm²
„ 1 year	365	292	441	167	133	250	434	340	598	190	149	307	„

	Cement A.	Cement B.
Standard Sample (1:3; 28 days in water)		
Tensile Strength	28·2	20·2 kg/cm²
Compression Strength	399·0	169·0 kg/cm²
Residue on the 5000 mesh sieve	15·1	36·2%
„ „ „ 900 „ „	2·0	7·8%
Weight of 1 Litre not heaped-up	1237 g	1414 g

Chemical Composition.

	Cement A.	Cement B.
Loss by Calcination	0·65%	1·58%
Analysis calculated on the Calcined Condition.		
Insoluble Residue	0·11%	0·10%
Silicic Acid	22·17%	22·55%
Oxide of Iron	1·98%	2·56%
Alumina	6·18%	8·35%
Lime	67·20%	64·11%
Magnesia	0·92%	1·05%
Sulphuric Acid (SO_3)	1·28%	0·56%
Alkalis	Residue	Residue

With these four cements, cubes of a sectional area of 50 sq. cm. were produced in mixtures of 1 of cement to 2 of sand and of 1 of cement to 4 of sand respectively, for strength tests to be continued up to a 10 year's hardening in fresh water, sea water, and open air respectively.

On account of its low percentage of lime and of the coarser grinding, Cement B, gave lower absolute strength values than Cement A, in the standard sample and, consequently also, at the experiment.

The speaker called attention to the strength tests after immersion of the samples in sea water, one-year's results of which are given in the following table.

For all mortars, the power of resistance to sea water is weaker than that to fresh water. In spite of its low percentage of sulphuric acid, Cement B shows less strength in sea water than Cement A.

The increased percentage of sulphuric acid occasioned by the addition of plaster of Paris produces an increase of strength both in fresh and in sea water. Thus the durability of the cement in sea water is not influenced unfavourably by the high percentage (2·5%) of sulphuric acid.

Further, concrete broadstones of $^3/_4$ cub. m. content were made in all four cements mixed in the proportions 1 of cement to 2 of sand and 3 of broken granite stones, and, after six months hardening in air, were immersed in the jetties, where they were exposed to chemical action and to the full brunt of the waves of the North Sea.

In a second series of experiments, slabs of 50 cm. × 50 cm. × 8 cm. in mixtures of 1 to 2 and 1 to 4 were made, and, after hardening periods of four weeks and 6 months respectively, were laid on the pier in the shallow estuary, where they were exposed to ebb and flood.

Last week a committee of delegates of the "Association of German Portland Cement Makers" accompanied by a representative of the Royal Laboratory for the Testing of Materials proceeded to Sylt to inspect these plates, and the speaker requested that Dr. Goslich now communicate the result.

Dr. **Goslich** (Stettin) reported that parallel tests had been made on Sylt with concrete slabs made of the French cement B

poor in sulphuric acid; these plates were exposed to the action of the water of the North Sea. It was found that the B plates showed cracks and clefts, while the A plates remained absolutely intact.

Also larger blocks made of 1 of cement to 2 of sand and 3 of broken granite stones behaved in the same way as the plates. The blocks of the B cement were attacked in such a manner that the granite stones were laid bare. In view of the results obtained, it can fairly be said that the requirement of the Argentine Republic, to the effect that only cements poor in sulphuric acid be used for sea water structures, is a very mistaken one.

Prof. M. **Möller** (Brunswick) completed his report.

The Use of reinforced Concrete beside the Sea (XL_8).

Thirty years ago he built a small experimental work on the shallow coast of the North Sea, at about 50 m. from the shore, so situated that ebb and flood placed it under water and left it dry again in 24 hours. He prepared slabs of 7.5 cm. in thickness provided with round reinforcement rods 8 mm. in diameter. His intention was only to study the action of the atmospheric influences and not the construction. The composition was 1 of cement to $2^1/_2$ of sand and 2 of gravel. The slabs held extremely well for 13 years, except at four localised points, without showing either interior or surface alteration. At the four points in question, however, the concrete had crumbled within the last few years. The iron reinforcements have shown no trace of rust where they were covered with 5 mm. of concrete or cement-mortar and did not lie quite close to the surface.

In contrast to the good behaviour of the slabs, which were 40 days old at the time of their application, the speaker drew attention to the softening and whitish appearance assumed by the concrete and cement-mortar materials of the experimental structure thus immersed in the sea, shortly after manufacture.

Mr. **E. Maynard** (St. Nazaire) wished to make a few observations in reference to the reports presented.

In regard to the reports of Mr. Bied, he assumed that he had made studies with water containing sulphate, but he had not given an explanation of the facts observed. The speaker would give a condensed explanation. The main point was the different action of the sulphates of lime and magnesia. The cements that

contain no alumina became decomposed in the solution of sulphate of lime, and withstood the sulphate of magnesia.

Since 1885 the speaker had pointed out that the blocks of lime from Teil became softened under the influence of the sulphate of lime which the very basic salts of lime, the silicates, the aluminates, &c. appeared to decompose by some action not yet known. The very calcareous cements can therefore easily be decomposed by this sulphate. On the other hand, if the same mortar be immersed in water containing sulphate of magnesia, the lime diffuses, while the sulphate of lime then formed can penetrate into the mortar in very small quantities only, and can exercise scarcely any action on the combinations poor in lime, which remain behind; the mortar accordingly decomposes without swelling. This is the explanation of the phenomena observed by Mr. Bied.

The second phenomenon observed bears reference to the good behaviour of the puzzolanas and of the dehydrated clay, and may be explained as follows: — the decomposed mortars always contain silicate of alumina and hydrocarbonate of lime. Now the speaker had shown that the puzzolanas must contain alumina in order to re-establish the clay after the action of the salts. A mixture of cement with de-hydrated clay, which combines with lime, will, therefore, when brought into contact with sulphate of lime, behave well when it contains little lime; when, however, it is introduced into a solution of sulphate of magnesia, the lime will diffuse and the hydrated silicate of alumina will form again; part of the lime will combine with carbonic acid and give the mortar its cohesion. The combination of the carbonic acid with the air is not capable of preventing the decomposition of the mortar.

It follows from these explanations that it is, properly speaking, not the sulfo-aluminate that causes the swelling of the mortar, but the supplemental hydration and the softening and decomposing action of the sulphate of lime on the very basic combination of lime, the silicates, and aluminates &c.; this is the reason why the cements take up more sulphate than is necessary for the formation of sulfo-aluminates, &c. With monocalcic cements no swelling takes place.

A high percentage of lime is more dangerous than an excess of aluminium, and good cements may be made with a large proportion of aluminium, but with little lime.

In addition to the softening and decomposing action of the sulphate of lime, which the speaker had observed since 1884, there are two additional important factors, namely the supplementary hydration and the diffusion of the lime. These are the preponderating ones.

The sulfoaluminate plays only a subordinate part; it is at the same time certain that the sulphate of lime has a greater affinity for the combinations rich in aluminium than for the very basic silicates.

The conclusion at which Mr. Maynard had so often arrived, was that the cements intended for marine structures must contain little lime.

In reference to Mr. Czarnomski's report, Mr. Maynard observed that the inspection of blocks in certain Russian harbours had again confirmed the results obtained with the blocks submerged at La Rochelle since 1852. Since, however, the compositions of the mortars were given in weight percentages and not in units of volume as recommended by him, it was not possible to give account of the degree of decomposition of the blocks.

Mr. Czarnomski considered the decomposition due to the diffusion of the lime, to the precipitation of the magnesia and probably to the sulfoaluminate. These actions comprehend only a part of the actual process; in order, therefore, to explain the effect of the sea water, we must add to the causes above adduced the other phenomena which the speaker had gone into in the course of previous studies, and which he could not reproduce here.

In reference to the view expressed by Mr. Feret that there is no process in existence by which the resistance of the cements to attack in sea water can be determined, Mr. Maynard said this determination must, by reason of the diffusion which he discovered and made known in 1901, be made in such a manner that the cement is brought into contact with the sea water itself and the changes in its composition determined analytically. This method, which gives the behaviour of the cement after the lapse of a year, the speaker had described and applied.

Finally the author wished to give an explanation of the softening of the Portland cement on being immersed in sea water too soon after its production as described by Prof. Möller.

The setting of the cement is due chiefly to the hydrate of lime, which, with the salts at the surfaces of the grains, causes an adherence of the particles. Now if use be made of a highly-rated cement, which in its process of mixture sets little lime free, and this be after a little time immersed, the hydrate of lime will then dissolve, diffuse itself, and become transformed into sulphate; the mortar will become soft, because no lime remains to make it cohere. If very little water be used in the production of the reinforced concrete and the latter be then almost at once immersed in sea water, the weight of lime which becomes hydrated is small, and the latter consequently dissolves, whereupon it diffuses itself and is transformed into sulphate, and the mortar loses its cohesion.

A similar action takes place when too little water is used in the production of concrete. The white efflorescences are formed by the disengagement of magnesium and carbonate of lime.

In the production of concrete for use in sea water care must accordingly be taken that as much water as possible be used (in order to produce as much hydrate of lime as possible) and also that the concrete be rammed as tightly as possible. Mr. Maynard had accordingly laid down special rules for the avoidance of these defects.

Mr. **A. Poulsen** (Lemwig) had intended to read an abstract of his report

Cement in Sea Water (XI_4),

which all the members of the Association had received in the form of a separate pamphlet.[1]) In view of the shortness of the time, however, he would only say a few words, especially as the abstract itself was to be published in the "Communications". He observed that the tests on concrete in sea water had as yet extended only over ten years, which he considered to be too short a period. The principal causes of the destruction of the blocks are wave action and the alternation of freezing and thawing, and further the actions of drying during the ebb and wetting during the flood.

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[1]) Cement in sea water. Report on the tests conducted by the Association of Scandinavian Portland Cement Manufacturers since 1896. Report by A. Poulsen. Gad Publishing House, Copenhagen 3 frs.

Prof. **M. Gary** observed that in Germany great importance had been attached to the choosing of three typical cements, very exact chemical analyses of which have been made. He thought it was not right to say that 5 years was an insufficient period from which to draw preliminary conclusions. Moreover, the German tests also were being continued. When, however, the cements have behaved well during 5 years, the assumption must at least be made that they will continue to do so. The structures are not intended to be everlasting but are only counted upon to last a certain time.

Mr. **E. Candlot** (Paris) observed that all hydraulic cements were under certain conditions, decomposed by sea water. With a good Portland cement and a compact mortar, great durability in sea water could be attained. In order to obtain the maximum of compactness, a good sand was required; as a rule too little attention was paid to this point. The addition of puzzolanic material had been advocated, and especially a trass, roasted &c. but the — perhaps favourable — influence of these had not yet been conclusively proved; it appeared to make itself felt principally in an increase of compactness.

The part attributed to the puzzolanic materials is that they combine with the released lime and prevent its escaping from the mortar and leaving it poorer in lime. It appears, however, that this result may be obtained with greater certainty by the use of a cement in which lime is present in the smallest quantity possible and which will part with only very little of it during the setting process.

The speaker had made an artificial cement which contains little lime and into which he had introduced a certain quantity of plaster of Paris before the burning. Thanks to the presence of the sulphate of lime, the cement can be burnt without suddenly crumbling to powder, as is always the case when the percentage of lime is reduced. The burnt cement contains only 5 to 6% of sulphate of lime, and, as experience shows, this is not detrimental. Mortars made with this cement have stood well for 10 years in solutions of sulphate of magnesium and sulphate of lime. The percentage of lime can be reduced to 50, and it had been observed that, at the instant of setting and during the first days of the hardening, no separation of hydrate of lime makes its appearance as in the case of the Portland cements.

Mr. **A. Foss** (Copenhagen) in his capacity as member of the organising committee directed the attentions of the meeting to the excursion to Lemvig, where the members would have a good opportunity of convincing themselves as to the results obtained by the Engineer in Chief Mr. Poulsen. He wished to lay stress on the circumstance that the proper composition of the mortar was the main point, and he, further, refered to the concluding sentence of the report of Mr. Poulsen, who in his resumé said that Portland cement, when properly applied, was in fact, not very subject to chemical action, and that the destruction of the large blocks, provided they be made with sufficient compactness, was to be attributed to climatic influences.

In regard to the communication of Mr. Candlot, the speaker added that it was really possible to make a cement which was not attacked by the sea water, and referred to the invention and patents of the Swiss cement engineer, Mr. Gresly. Mr. Gresly's cement was made of lime, clay, and plaster of Paris. Tests which were made in the speaker's laboratory, in concentrated saline solutions as well as in sea water, had shown that this cement was not attacked at all by sea water. Whether this will be of practical value in the future, he was unable to determine.

Dr. Ing. Rud. **Dyckerhoff** (Amöneburg) did not understand why cements rich in sulphuric acid, whose percentage of this chemical had no deleterious effect in fresh water, should be attacked to a greater extent while hardening in sea water, than cements poor in sulphuric acid. Experiments have shown that cements rich in sulphuric acid have behaved very well in salt water up to a percentage of anhydride of sulphuric acid of 2·5. He did not believe it to be necessary to extend the test period over more than 10 years, as advised by Engineer in Chief Poulsen.

Mr. **I. Laborbe** (Paris) drew the attention of the Meeting to several tests be had carried out on the invitation of Mr. La Chatelier. He found that the addition of hydro-cellulose, (obtained by the oxidation of cellulose by hydrochloric acid), succeeded in counteracting the effects of sea water and sulphated water on the lime which existed naturally in cements, a was rendered free by the setting reaction. Hydro-cellulose gave off carbonic acid which carbonated the lime in the mass of mortar, gradually as the setting reaction left it free.

Mr. **E. Leduc** (Paris) considered that the question of the power of resistance of cement in sea water can be solved by synthetic tests with cements of this kind containing different quantities of silicic acid, aluminium, lime, &c. These cements must then be exposed to solutions of the different elements which the sea water contains. He submited the following resolution to the assembly:

> "The Congress proposes that a few manufacturers be "requested to make some cements of different compositions. "These cements are then to be examined at different testing "places, in artificial as well as in natural sea water which "contain the different ingredients separately or mixed, as "for instance solutions of common salt, sulphate of magnesium, "sulphate of magnesium and common salt, &c."

Mr. **R. Feret** (Boulogne sur Mer) had pleasure in establishing the fact that the observations reported by Mr. Gary agreed with those which he himself had made a long time ago. The circumstance was indeed well known that thoroughly compact mortars withstand the decomposing effect of sea water best. As to the tests themselves, on the basis of which Mr. Gary had decided — as the speaker himself had already done — that the additions of puzzolana improve the cements, they contradict the previous experiences, on the basis of which Mr. Dyckerhoff had made a pronouncement in the opposite sense.

This improvement was not to be ascribed solely to a physical effect as Mr. Candlot asserted and the tests which were brought forward in this sense by Mr. Candlot extended over a long period. The speaker had shown by means of cement mixtures, which were made partly with finely powdered puzzolanas, partly with indifferent materials of the same fineness, that the first mixture withstood decomposition much better than the second one.

Mr. Feret observed in reference to the cements made of mixtures containing large percentages of clay to which a considerable amount of plaster of Paris was added before the burning, that he had had an opportunity of testing cements made by Mr. Candlot as an experiment, and that, although offering little resistance to mechanical tests, they had behaved well in sea water for several years. He believed that these cements were worth studying.

Dr. Ing. Rud. **Dyckerhoff** observed that laboratory tests were much less valuable than practical ones. The Gary tests, therefore, which were made under actual conditions in sea water, were of more value than those of Mr. Feret.

Mr. **E. Candlot** (Paris) recalled the circumstance that the cement patented by Gresly, to which reference had been made by the President, was the same as that of which he had himself spoken.

Gresly had intended to produce a white cement. He himself had intended to produce a special cement which would withstand the sea water, and they had come to an agreement beween themselves in regard to the production of this cement.

Mr. **W. Czarnomski** (St. Petersburg) did not wish to belittle the excellent qualities of Portland cement in sea water — with regard to the uniformity of its chemical composition, its great power of resistance to compression and tension, and its constancy of volume — but he found that these qualities of Portland cement were not sufficient. He believed, that in sea water the chemical actions were far more dangerous than the mechanical ones. An addition of puzzolana was a very good means of preventing decomposition, and he also believed that the before-mentioned white cement was of interest especially for harbour engineers.

Dr. Ing. Rud. **Dyckerhoff** observed, that in some of the series of tests in the Poulsen report the test-samples were exposed to the open sea, but in others they were protected from the action of the waves. Two series of tests such as these could not be compared.

Mr. **Ed. O. Sachs** (London) gave reasons for and proposed the following resolution:

Cement in Sea Water.

The Congress recommends the appointment of a small committee

a) in order to obtain by December 1910 any additional information or supplements to the reports presented at the Congress of Copenhagen, they may require;

b) to summarize these reports and supplements and to present the summary of the results in a brief form to the next congress;

c) to collect information on the effect of sea water on Portland cement sea structures of more than 25 years' standing;

Dr. **Goslich** proposed that the resolutions proposed by Mr. Leduc and Mr. Sachs be printed and distributed among the members on the following day before the vote is taken.

The **President** agreed and adjourned the proceedings till the following day at 9·30 a. m.

Second Meeting, Thursday, September 9th, 1909.

Chairman: Capt. **Grut,** of the Engineer Corps.

The **Chairman** opened the Meeting at 9·30 a. m. for the continuation of the discussion of the question of "Cement in sea water".

Mr. **Colomb** (Paris): In the report of Mr. Poulsen on the experiments which had been made during the last ten years by the Association of Scandinavian Portland Cement Manufacturers, the French products were represented by the lime of the Le Teil works. The speaker quoted from pages 22 and 24 of the report, that the laboratory tests with the lime had given good results, but that they had not proved satisfactory on the northern Scandinavian sea coast, the reporter arriving at the conclusion, that lime from Teil of rich mixture comes short of the poorer Portland cement in strength; but that the poor lime mortar was from the beginning destroyed by the action of the frost and of the subsequent thawing, and that the testing in Vardo tends to justify the conclusion that the destructive mechanical action had accelerated the chemical destruction proceeding simultaneously.

The speaker wished to call attention to the circumstance that the lime from Teil had never claimed to attain the strength of the cements. On the other hand Teil supplied, for work in sea water of medium temperature, a cement which decomposes to a slight extent only and is cheap. In his letter to the Chairman of the Committee, which is printed in the report, Inspector General Guerard laid special stress on this, and emphasised the advantages and the suitability of this lime in connection with the harbour works in Marseilles.

It was certain, that, in presence of the raw climatic conditions of the Scandinavian tests, the lime, as compared with the Portland cement, could at the outset play no very distinguishing part. The alternation of freezing and thawing, again, to which the action of the waves is added, must necessarily cause cracks in a slowly-setting product of medium strength which open the door to the chemical action of the sea water. It would perhaps have been desirable in such high latitudes to make use of a lime of a richer mixture than that which Inspector General Guerard had declared to be satisfactory for the comparatively warm water of the Mediterranean Sea. He observed that Mr. W. Czarnomski had, in his report, established the good results of the lime from Teil in some of the Russian harbours of the Black and Caspian Seas. He must also express his regret that the comparative tests were not extended also to the cement from Teil, as was intended by the Committee. On the whole, moreover, no very distinct differences could be observed from the photographs accompanying the reports between the appearances of cube No. 11 and cube No. 3, which were made of lime from Teil and of Scandinavian cement respectively.

Dr. Ing. **Rud. Dyckerhoff** (Amöneburg) reported on some tests on the chemical action of sea water on the inner core of the concrete. Three years ago in Brussels, he had already communicated the fact, that the Association of German Portland Cement Manufacturers had made tests and had had the inner core and the 5 mm outer shell of the samples which have been hardened in sea water during a period of 10 years, analysed. It had here turned out, that chemical changes had taken place in the outer shell—that some lime had been lost and some magnesia taken up, and this principally in the case of pure mixtures. In all cases, however, the composition of the inner core remained unchanged.

Mr. **Laborbe** (Paris) did not understand why Mr. Leduc's resolution was restricted to synthetic cements, especially if, by synthetic cements, Mr. Leduc understands artificial Portland cements which, strictly speaking from the chemical point of view, are not synthetic cements. He asked further, why it did not extend to all cements, whatever be their method of manufacture.

Dr. **O. Lieven** (Novorossisksaid) — According to Mr. Candlot's statement, his material consisted of Portland cement with an addition of 25 per cent of plaster of Paris. The plaster of Paris was

added to the material before the burning. Mr. Candlot stated that owing to the circumstance that a combination of sulphuric acid was already present, the sea water did not introduce any further sulphuric salts nor impart other elements. It was also said that laboratory tests of many years' duration had proved the durability of the material. The speaker considered that no sulphate of lime would be present in the material at all.

This is added before the burning, when the material has to withstand a temperature of more than 1200^0, like the other elements that are to be burnt into Portland cement. In the "Tonindustriezeitung" Prof. Glasenapp of Riga had elucidated the question of the plaster of Paris cement (Estrichgips). At the high temperature mentioned the plaster of Paris was transformed into a double combination of sulphate of lime and calcium-oxide. This is a combination analogous to that of Portland cement (a combination of silicate of lime with calcium-oxide). He could not understand why the sulphuric double combination of the lime should be attacked to a less degree by the sea water than the silicate. Add to this, in the burning of the mixture in accordance with the Candlot proposal the process is by no means so simple as that in the preparation of the plaster of Paris cement (Estrichgips). In what manner the silicic acid of the Portland cement combination acted on the sulphuric acid combination in the burning process, cannot as yet be precisely stated. The material proposed by Mr. Candlot had no chemical individuality, but is arbitrarily put together. The speaker could not therefore recommend the adoption of Mr. Leduc's motion.

The **Chairman** put the Sachs proposals a), b) and c) to the vote, and also the Leduc proposal in the following form: — d) that a number of tests be made in the manner proposed by Mr. Leduc. Proposals a)—d) were adopted.

The **Chairman** thanked all who had taken part in the discussion for their valuable communications and invited Prof. **v. d. Kloes** (Delft) to present his report on

The Consequences of the Use of Mortar of Improper Composition (XIII$_4$).

Prof. **A. v. d. Kloes** regretted that many engineers are still blind to the fact that without a certain percentage of sand the mortar

wastes away and separates from the stone. Even municipal regulations of larger towns in Holland still prescribe, for certain purposes, so-called strong trass-mortar, that is to say, a mixture of trass and lime without sand. According to what had been said already, a mortar of this kind causes a falling-out of the joints of the wall, a looseness of the covering layers of quay and dyke walls. These phenomena were generally ascribed to the frost. Many people even entertained the idea that trass-mortar was not frost-proof.

A second cause of the destruction of masonry in trass-mortars with little or no sand was the incorrect proportion borne by the lime to the trass. It is in every way desirable that trass and lime be mixed together in about the proportion of 5 to 4 units of volume, as in the case of puzzuolana cement. An excess of trass remains behind in the mortar unattacked and will cause no difficulty. On the other hand, an excess of lime was the cause of all sorts of evils that are met with every day. The fine particles of trass were often, so to speak, swallowed up by the lime paste; a solid body indeed results, but a body which is very receptive of water, which is liable to be washed out, and which causes efflorescence as well as wall-rot.

The speaker, then, as an outcome of years of observation, recommended the following prescriptions for the composition of mortars made of trass and cement.

Poor Lime	Rich Lime	Lime Paste	Trass	Portland Cement	Puzzuolana (Trass-Lime) Cement	Sand
a) Thoroughly waterproof mortar which remains continuously under water.						
1	—	—	$1^1/_4$	—	—	$1^1/_2$
—	1	—	$1^1/_2$	—	—	2
—	—	1	3	—	—	4
—	—	—	—	1	—	2
—	—	—	1	1	—	$2^1/_2$
—	—	—	—	—	1	1
b) Quay and lock walls &c.						
1	—	—	$1^1/_4$	—	—	$2—2^1/_2$
—	1	—	$1^1/_2$	—	—	$2^1/_2—3$
—	—	1	3	—	—	5—6
—	—	—	—	1	—	3
—	—	—	1	1	—	4
—	—	—	—	—	1	$1^1/_2$
c) Foundations and building.						
1	—	—	$1^1/_4$	—	—	3—4
—	1	—	$1^1/_2$	—	—	4—5
—	—	1	3	—	—	8—10
—	—	—	—	1	—	3
—	—	—	1	1	—	4—5
—	—	—	—	—	1	3

If Portland cement is to be perfectly waterproof, it must not contain more than 2 volumes of sand to 1 volume of cement. In air, masonry made with this mortar decomposes and in no case may more than $2^1/_2$ volumes of sand be mixed with 1 volume of cement.

If, however, for the sake of ecomomy or ease of working, lime be added, the most dangerous mistake as regards efflorescence and wall-rot will have been made.

Two modes of attack of the masonry by wall-rot must be distinguished: — 1. a corrosion from within and from without, (wall-rot proper) and 2 a separation of scales, sometimes very thin but often of considerable thickness, which, by accumulation and infiltration of strange matter into the pores, are made to peel off from the surface.

The cause ot the destruction of the stones appears to lie principally in the circumstance that the crystallisation of the salts in their pores is accompanied by increase of volume, which breaks up the neighbouring parts. The dissolution of the efflorescence by rain and the re-crystallisation by drying make it possible for the same saline particles repeatedly exercise their action.

This phenomenon shows itself in a greater degree when salt water is used in the preparation of mortar than when fresh water is applied to this purpose. It shows itself, not only with bricks, but also with clayey sandstone, and especially with trachyte. In regard to the latter, the author had in mind the Cologne Cathedral, which he had inspected. What he had seen there had exceeded his worst anticipations.

As far as the author was aware, these phenomena did not show themselves with limestone and artificial silicic limestone.

It seemed to him to be beyond all doubt that most oı the weathering phenomena observed in buildings had their origin less in the stone itself than in the mortar which binds it together. For scientific investigation we here have an extensive, almost untouched, domain. The speaker would like to propose "that the Association include it in the field of its labours, and also that it appoint a special committee for it".

In the use of trass mortar in accordance with his rules, which had thoroughly proved their excellence in practice, the damages referred to never showed themselves. The same favourable

results were obtained with mortars with additions of trass instead of lime. In addition, trass renders the Portland cement insensible to the action of the sea water. In some hydraulic works the speaker had obtained good results with a mortar of 1 of cement to 1 of trass and 4 of sand, and excellent reservoirs for rain water had been made with 1 of cement to 1 of trass and 3 of Sand. The maximum efficiency of trass would be obtained when it is mixed with the cement at the outset. There is no objection, then, to an honest business transaction consisting in the mixture of cement and trass in equal volumes. Both the contracting parties would profit by it, the more so that there are brands of cement in existence the strength of which are increased by 10 per cent by this mixture.

The speaker then adduced a number of examples of the bad effects on the durability of the masonry by the use of cement-mortar rich in lime. Amongst other things, he said that the mortar of the old fortifications near Utrecht, when seen from a distance, appears to be running out of the walls in white streams.

Improperly made masonry falls to decay more rapidly when it is occasionally submerged in water. A consequence of this is the corrosion which so often occurs in the masonry of quays and piers and in the pillars of railway bridges at the level of the water. The deterioration is the more rapid the greater the speed of the current.

In addition, where such rich mortar is employed, no cohesion can exist between the facing of natural stone and the brick walling; an uneven setting is then the inevitable result. The looseness of the masonry, where it is present, may be plainly observed in the dull sound given forth by it when hammered.

Another peculiar phenomenon may often be observed on old thick masonry, viz, the separation and swelling out of a crust of about the breadth of a brick. This may be explained in the following manner: — a mass of masonry absorbs water, which follows the line of least resistance, that is to say, goes to the exterior. This exterior surface, moreover, is the part most attacked by the rain. The masonry joints at the surface, together with those behind the bonders, are easily saturated with water and become distended by the frost. Horizontal and vertical strains are thus produced. The horizontal strains burst the joints of the walls

behind the bonders and at the same time break the mortar; the vertical strains produce the flexure of the loosened scale.

The speaker further gave some interesting cases, where, by reason of the use of the mortar rich in lime, the masonry was spoilt by efflorescence and scaling. Thus an old Dutch brick gable in Leyden, which had borne the brunt of centuries, when pulled down and erected again in another place with mortar of cement and lime, was now corroded in numerous places. Similarly in the case of a works-chimney, which, three years after its erection, was in such a state of dilapidation that it had to be pulled down, in spite of the circumstance that the hollow brick material was in very good condition and the stresses to which it was subject were small. Again the leakage of some of the valley dams that have been built during the last decades in Germany are to be attributed to similar causes.

Worthy of remark, again, was the effect of the cement-and-lime mortar on glazed tiles which are cemented to the wall. The walls contain numerous hair cracks. On the masonry and between the tiles, the same velvety efflorescence is seen as in rough surfaces oft walling; in the pores and under the glaze the same salts crystallise out, and the surfaces of the tiles and of the bricks peel off in shell-like fashion; this shows itself to the greatest degree in some railway station tunnels, e. g. in Cologne, Königswinter, and Delft.

Dr. Rud. **Dyckerhoff** (Amöneburg) called attention to some series of tests on trass, trass-cement, and cement-lime mortars, made by Dr. H. Renezeder in Vienna, and to similar ones on cement-lime mortars made with an excess of lime.

Mr. **G. Herfeldt** (Andernach-on-the Rhine) Dr. Renezeder had made tests with cement-lime mortar with an excess of lime. These lime mortars attained great strength within a short time. This was, however, only a small series of laboratory tests extending over a period of 3 months only, and we must, therefore, be careful not to draw conclusions from them in regard to their behaviour under actual conditions, because the effect of the excess of lime could not show itself within this short time. The speaker was of the same opinion as Prof. v. d. Kloes in regard to the injuriousness of the addition of lime to the cement-mortar, and agreed with the experiences referred to by him. He must, accordingly, give warning

against tests of too short a duration, which yielded results opposed to the real circumstances.

Dr. Eugen **Dyckerhoff** (Biebrich) added a few observations to the report of Mr. v. d. Kloes. The masonry of a bridge in Mayence had been attacked, while the mortar was so good and waterproof that the water could not penetrate it. The stones, however, were wet through, so that they were subsequently split by the frost. He supported the proposal of Prof. v. d. Kloes that a committee be appointed.

Prof. v. d. **Kloes** (Delft) wished to lay down the following principles:

1. Compact mortars can waste in air and are therefore not to be recommended.
2. Mortars may be compact and still in a high degree liable to be washed out.
3. Compression and tensile tests are a poor measure of the quality of mortars in actual practice; very firm mortars may cause efflorescence and wall-rot.

The **Chairman** proposed the following resolution:

> "A committee is to be formed for the purpose of in-
> "vestigating the influence of incorrectly composed mortar on
> "the weather resistance of the masonry."

Dr. Eugen **Dyckerhoff** moved that the word "incorrectly" be struck out of the resolution. The decomposition was also caused by the joints of the masonry. He proposed that the resolution be modified so as to read: ". . . to study the destruction of the stones and the joints of the masonry."

Dr. **Müller** (Rudersdorf) proposed that the investigation be extended to the stones of the walls also.

Dr. **Tannhäuser** (Berlin) considered the statement of Professor v. d. Kloes to be possibly correct as regards artificial stones, but not as regards natural ones.

After short observations from Dr. Nagy (Budapest), Dr. Eugen Dyckerhoff and Prof. v. d. Kloes, the following resolution was read by the Chairman:

> "A committee is to be formed for the purpose of
> "investigating the influence of the composition of the

"mortar and the quality of the building stone on the "weathering of the masonry."

This resolution was adopted by the Section.

Dr. Ing. v. **Bresztovszky** (Budapest) summarised his report

Contribution to Methods of Investigation into the Elastic Longitudinal Deformation of Concrete ($XIII_3$):

He had made a series of repeated compression tests on concrete prisms of $15 \times 15 \times 60$ cm (length for measurement 43 cm) with from 30 to 100 repetitions, each, of load and release per minute. The alterations of form were illustrated graphically, the abscissae giving the increase of alteration of form and the ordinates the numbers of repetitions. These repetition-curves are concave to the axis of the repetitions. They would be parallel if the alterations of form were to reach a limiting value. In order to obtain a limiting value experimentally, the numbers of the repetitions would have to be continued far beyond those given.

In order, in the case of compression tests, to find the permanent and elastic alterations of length without repetitions, the tests would have to be made in the manner communicated by Prof. Rejtő. The load is uniformly increased by 1 ton per minute without jar to P_1 and (return being in each case made to the initial load P_0) is then increased from P_0 to P_2, and so on until fracture occurs, and the alteration of form is read off for each increase of load of 1 ton, i. e. for all values between P_0 and P_1. For the coefficient of extensibility, it was advisable to take the value which is shown by such tests without repetition. From the diagrams of work he established the following laws:

1. The law of elastic contractions is expressed by Hooks law. In the less hard kinds of concrete the coefficient of extensibility, which, below a proportionality limit, is constant, depends on the magnitude of the force which causes this proportionality limit. In the case of hard concrete, on the other hand, the coefficient of extensibility is constant almost up to the breaking limit.

2. The law of permanent contractions is in each case expressed by a curve convex to the axis of loading, which increases up to a certain maximum.

The **Chairman** thanked the speaker for his communications, and Prof. Kirsch (Vienna) for the report presented by him:

"The Bonding of Layers of Mortar after Different Time Intervals" ($XIII_1$)

and Dr. Renezeder (Vienna) for his report:

"Notes on Trass, Trass-Cement and Cement-Lime Mortars."

Hereupon the **Chairman** brought forward the question:

"Progress in the Methods of Testing Hydraulic Cements"

for discussion. The reports of Messrs. Feret (X_1), Prof. Schüle (X_2) and Prof. Zielinsky (X_{12}) were to be taken together.

Mr. **R. Feret** (Boulogne sur Mer) gave a critical résumé of his report on the present state of the question of the testing of hydraulic cement and on the position taken towards it by the Association.

For chemical investigations, he considered the establishment of a uniform method desirable, which should be made use of at any rate in contested cases.

The determinations of the specific gravity and of the apparent density respectively can now be made in a fairly definitive manner, but the practical value of the results which they gave was still matter of dispute.

Sifting gave a very unreliable measure of the fineness of grinding, and should be replaced by simpler and more definite methods by air process than any of those which have up to the present been proposed.

The constancy of volume was now tested by a number of contradictory methods; the most practical and efficacious of these appear to be that of Le Chatelier with needle-rings.

It would be desirable that a rapid method of testing the liability to decomposition of various cements by sea-water be established.

For the testing of the duration of the time of setting, the calorimetric method did not appear to fulfil the promise which it gave.

The tests of strength were still very much open to improvement, and we are still a long way from the establishment of a standard

method of conducting them. A special committee was at work on these, and its attention was devoted principally to the questions of standard sand and plastic mortar.

From an acceleration of the strength testing methods by the use of hot water, nothing was to be hoped.

The testing of the power of adherence was one of the greatest practical importance, but as yet no method effecting it had been officially accepted. The reporter had, at the last Congress, requested that several testing establishments should re-test the process proposed by himself. It may be observed that the adherence proper must not be confounded with the resistance to slipping of the iron rods in the reinforced concrete, a resistance which was the resultant of various forces, each difficult to estimate.

The uniform testing of the Puzzuolanas is beset with great difficulties, which it had not yet been possible to overcome. The reporter was of opinion that the solution of the question must be sought in a chemical process.

The reporter finally established the fact that, apart from the old testing methods which were adopted without any alterations of consequence by Committee No. 22, the International Association had not accepted a single one of those worked out by its committees, and that these committees themselves had not yet considered themselves in a position to offer proposals in favour of one or other of the new methods.

At first sight a pause of this kind might appear regrettable. It would however, be evident that — in regard to the choice of methods of testing, which it was to uphold with the weight of its authority — the Association had to be especially cautious, and that it should officially patronize only such methods as had previously been re-tested and found suitable by a sufficient number of investigators.

According to this, the task before the Committees of the Association chiefly consisted in the working out of better testing methods than those at present employed, the checking of the correctness of these by means of parallel tests in different testing establishments, and their improvement again where necessary. When we had once got so far, these testing methods would find places for themselves in the world of engineering, and the Association would only have to impress on them the stamp of its official recognition.

Prof. **F. Schüle** then presented his report on

"Plastic Mortars" (X_2).

The report of the Committee gave an account of what had been done up to January 1909. Since then the tests had been continued in various laboratories. For the determination of the strength of standard mortars of plastic consistency by means of prisms of $4 \times 4 \times 16$ cm, they could be described as extremely favourable. The difficult question of the determination of the mixing water had, as regards Portland cement, been solved by Mr. Frey, of Luterbach, who proposed to take for each sample the same weight and proportion of cement, sand, and water, for a given kind of sand. A given weight of the mixed mortar was always to have the same volume. The test-samples would in consequence be of nearly the same degree of compactness, which is a matter of importance for the comparison of the results. The table distributed in the sections combines the results of tests with 5 cements by Mr. Bienfait in Amsterdam, with 10 cements by Dr. Framm in Karlshorst, and with 12 cements in Zürich, which were obtained, not only by the prism method but also by the ordinary one, with rammed mortar mixed in an earth-moist state. If the results of bending-tests with prisms and the tensile tests in the 8th mould, and those with crushed prisms and cubes of 7 cm length of side be compared, it will be found that the prism tests give a classification of the cements differing from that of the tests with rammed mortars. Since, however, the plastic mortars more nearly approach the cements used in practice, the classification given by them is of more importance than that obtained with rammed mortars, that is to say, with mortars in which the natural interstices have been artificially reduced in size. It can further be laid down, that the increase of strength in from 7 to 28 days in the case of prisms is greater than with the old method. The coherence of the cement makes its appearance more clearly in tests with plastic mortars. It is also apparent that the question of the compactness is solved by means of the prisms, while, when the Böhme hammer is used, differences of 0·05 to 0·10 (2 to 4 %) in the compactness of tensile-test and compression-test samples of the same cement show them selves. It was interesting to observe that the investigations of our Hungarian colleagues led them by other paths to the re-

commendation of test-samples in which the exact weight is calculated in advance for a given volume.

The question before us was not that of at once replacing the ordinary standard methods in the various countries, but that of attaining to an exactly circumscribed method of testing cements by the aid of plastic mortars. The proposed method by means of prisms was still capable of improvement, and Mr. Feret had made interesting experiments in this direction. It could, notwithstanding, be asserted that the labours of the Congress had made good progress towards the establishment of a uniform method, which was valuable for the institution of comparisons between the strength of the cements of other countries — an undertaking which, with the ordinary methods, was not possible — and it might be hoped that, by the meeting of the next Congress, the Association would have extended its sanction to this method and would be able to include it in the series of "processes recommended by the Congress."

Prof. Dr. **Sz. Zielinski** (Budapest) summarised in some detail the report presented by him on:

"The setting of Roman and Portland Cement as paste, in mortars and concrete" (X_{12}).

The object of the extensive investigations of the Hungarian Association, comprising, as they did, many thousands of tests, was the establishment of suitable standard tests for cements which differ in their nature from Portland cement, such, for instance, as Roman cements, which are not burnt so hard and contain a smaller percentage of lime than the first-mentioned material. The speaker showed from the report, what an important influence the addition of the water had on the strength of the test-samples in the cases of pure cement, mortar, and concrete respectively, and put forward a new system of control in which the specific gravity of the mixture was calculated in advance from the specific gravities of its individual component parts with a given proportion of mixture by weight, and in which, by suitable additions of water and suitable ramming, the specific gravity of the test-sample was said to be really attained also. The speaker illustrated his explanations by reference to a large number of tables.

Prof. **M. Gary** believed that the statements of Prof. Zielinski paid too little regard to the chemical individuality of the cements, and welcomed the proposal that a committee be appointed to go more closely into the matter.

In regard to the question of plastic mortars, the speaker did not overlook the great advantages which were attained by this process. Opposed to these, however, was the difficulty of the exact production of the test-samples, and, in particular, he would not like to see the process put into practical execution on the building ground. He thought that it would be premature were we now to attack the problem of the unification of the testing methods before that of standard sand had been disposed of, and he should like to move that Committee No. 42 investigate the question, whether the Freienwalde product be fit to serve as an international standard sand. The invariably uniform production of standard sand was ensured in Freienwalde, and by a modification of the sieves consisting in the substitution of the 144 mesh size for the 120 mesh one, it would unquestionably be possible to fulfil the international requirements. The differences in the sand would not exert any appreciable influence on the strength values of the test-samples, and he believed that, by the introduction of the Freienwalde sand, the question of the unification of the test methods would be brought a long step forward.

Prof. **D. v. Nagy** (Budapest) recommended that test-samples be made of plastic mortar containing from 40 to 60% of water. For the obtainment of correct results, it was necessary that the air be expelled from the test samples, in order that these may attain the weight calculated from the individual component parts; it was necessary, then, that the mortar be shaken until bubbles of air ceased to rise from it. He further recommended that pure cement be examined, since an admixture of foreign matter might easily lead to false results.

Prof. **F. Schüle** considered it useless to recommend an international sand. This question stood in close connection with that of the unification of the methods of testing, and a former committee had postponed it until the methods of testing could be made uniform.

Professor **N. Belelubsky** (St. Petersburg) recommended the Freienwalde standard sand for comparative tests but not for

general international use. He called attention to the circumstance, that at the Congress in Budapest in 1901 and also at various other congresses, a mixed sand (in contradistinction to sands with one size of grain only) was recommended.

Mr. **Rich. L. Humphrey** (Philadelphia) laid stress on the importance of the question of an international standard sand. In America the question had been under consideration for the last 7 years. Samples of mortar were there in almost exclusive use, and a uniform sand was, therefore, a necessity. A committee of engineers had there been appointed, which had recommended that crushed glass sand from Ottawa (Illinois) be made use of. He recommended that a committee be appointed to examine the standard sands of different countries, to compare them one with another, and if possible to propose a standard sand for general international adoption.

Dr. **Rud. Dyckerhoff:** In view of the investigations of the German Association, the latter had come to the conclusion that with pure plastic cement it was not possible to fix the setting time exactly.

Prof. **M. Gary** agreed with the remarks of Mr. Humphrey and called attention to the results of comparisons between different sands already communicated by himself (Mitteilungen aus den kgl. technischen Versuchsanstalten 1898, page 121).

Dr. **P. Prüssing** pointed out that the sheet of test-results which Prof. Schüle had communicated showed differences in respect to the sand, the samples obtained from Zürich and Karlshorst respectively having different specific gravities the explanation of which could only lie in the sand. In the standard samples the average specific gravity was, for Zürich 2·41 and for Karlshorst 2·33, while in the prism-samples the average was, for Zürich 2·21 and for Karlshorst 2·25; Zürich, then, had the higher specific gravity for the standard samples. He thought that this difference could only be due to the sand, and it was therefore necessary to solve the standard sand question.

On the motion of the **President** the further discussion of the standard sand question was adjourned till Friday and the reports

“On Rapid Methods for Determining the Strength of Hydraulic Cements” (X_4)

were brought forward for discussion.

Dr. **F. Berger** (Vienna) presented the report of Committee Nr. 9 on this question, which was also accompanied by a contribution on the same subject submitted by Mr. A. Greil (Vienna) and by one on hot water rapid-test samples by Mr. L. Deval (Paris). The reporter proposed the following resolution:

"The numerous test-results submitted are so "contradictory that the hot water test appears too "unreliable to be suitable for use for rapid tests for "the determination of the strength of the hydraulic "cements."

"The Congress therefore recognises the justifi-"cation of the motion, that the question as to the "utility of the hot-water test for the acceleration of "the strength tests of hydraulic cements be not pur-"sued further."

"On the other hand the tests of Mr. Deval once "more show how valuable these tests may become, "in giving an explanation of the tendency of the "cements to develop swellings and cracks."

This resolution was adopted.

The reporter further moved that, even though the hot-water test for the rapid determination of the power of adherence be not pursued further, the Committee for the study of the question of an accelerated method of testing be allowed to continue its labours. The individual members shall be invited to study this important question further, so that starting points perhaps after the elucidation of the chemical processes, may be obtained for the rapid determination desired. Results of experiments which may be obtained may then be communicated to the Chairman of the Committee.

This proposal was then adopted. The Chairman closed the proceedings at 2·10 P. M. and communicated the programme for the following day.

3rd Meeting, Friday, Sept. 10th 1909.

The Chairman, Capt. **Grut** opened the meeting at 9·30 a. m. and brought forward the question

"**Weathering Resistance of Building Stones**" (XII_1)

for discussion.

Prof. **Hanisch** (Vienna) presented the report of Committee Nr. 7. The Committee had formerly decided to take as the basis of their labours the work of Geheimrat Hirschwald, which had since been published, and the work of the committee appointed by the German Association for the Testing of Materials on the weathering of building-stones. The Committee would accordingly be in a position to take up their functions, in the exercise of which they also proposed to utilize the suggestions contained in the works "Proposals for the testing of Natural Building Stones as to Weathering" by Prof. Dr. J. Hirschwald (Berlin), "On the Theory of Frost Action" by Prof. Dr. Seipp (Kattowitz) and "On Resistance to Frost" by E Leduc (Paris). The speaker moved that the Section give its consent to the continuance of the work of the Committee.

The motion of Prof. Hanisch was carried, and a vote of thanks was accorded to all the reporters.

The **Chairman** then invited Geheimrat Prof. Dr. **Hirschwald** (Berlin) to deliver his promised lecture.

Prof. Dr. **J. Hirschwald** delivered a lecture illustrated by numerous views thrown on the screen, which was received with great applause and the most important points of which are given in the following:

On testing the various kinds of natural-stone used for building purposes, to ascertain their weather resisting qualities.

The testing of the various kinds of natural stone used for building purposes formed part of the programme sketched out at the first meeting held in Munich twenty-five years ago for securing unification in methods of testing materials. While, however, a number of other problems dealt with at that same meeting, especially those that apply to researches in regard to metals and cements, have for some time past, notwithstanding some still doubtful points, led to the establishment of testing standards that are now pretty generally received, the researches in regard to building-stone, particularly with reference to its weathering properties, have not so far yielded any practical results. This, however, may be sufficiently accounted for by the difficulties which have stood in the way of a solution of the problems involved in this particular instance. From the first, these problems did not resolve themselves simply in the ascertaining of the useful properties of a

material with a view to turning it to the best account, as has been the case with most of the other branches of research, but research had also to show and explain the variations occurring in the said properties in course of time and under the action of elements in the atmosphere, of frost, and to take into account weathering conditions under the action of running water.

Hitherto, there had been no scientific basis whatever likely to prove of assistance in clearing up the matter. It was therefore in the first place necessary, to study the progress of the weathering process on the kinds of stone which had been exposed for stated periods of long duration to the action of the atmosphere. The only means at hand to serve this special purpose were the buildings constructed of quarry-stone in which the duration of the weathering process could be accurately determined by the age of the buildings. There are a large number of such buildings, constructed of this material, the age of which varies from decades to centuries, and in which weathering can be observed in its various stages of progress. Specimens taken at great depths in an old construction further make it possible to ascertain what have been the original properties of the stone. By again selecting, with a view to comparison, buildings standing in open spaces and others located in large cities, also railway plant, bridges and harbour works, a good basis is obtained on which to form an opinion upon the different effects which the pure country air, the smoke and gas of cities, the dampness of the earth, river and sea water, have on the same kind of stone.

In order to show the suitability of such preliminary researches it suffices to mention that a Committee appointed by the Prussian Ministry for Public Works for instituting experiments in regard to building-stone in conjunction with the Building Survey Departments, the River Navigation Management Committees and the Railways, have made a series of these tests upon the best preserved and the most decayed portions of as large a number as 1056 old constructions, collecting at the same time specimens of the same stone freshly quarried in all cases in which the origin of the stone used in the buildings in question could be ascertained with certainty.

The large amount of different kinds of material thus collected has been examined to ascertain the properties which, arguing

from the experience so far acquired, might have an influence on the durability of the corresponding stone.

General results of researches.

The necessary preliminary condition for the establishment of a suitable method of testing stone for building purposes can be naturally defined after having ascertained exactly the processes which lead to its disintegration by the action of elements in the atmosphere. It could in a general way be taken for granted that the resistance of stone to this action depended both upon the stability oı the grain and upon the durabilites of the constituent forming the binding material of the grain i. e. the resistance of the cementing subtance forming the bond, to the effects of the disintegrating atmospheric conditions.

The test methods thereupon called for, may be classed under two headings, dealing with

1. Chemical disintegration or decay, due to the proportion of carbonic acid gas, oxygen, water and gaseous products of combustion in the atmosphere.

2. Mechanical disintegration, which may be subdivided as follows:

a) Disintegration due to the softening action of water and the consequent washing away of the softer constituents from the surface of the stone.

b) Disintegration due to frost, also to the alternating action of sun-rays resulting in a periodical expansion of the outer surface of the stone.

In the following remarks we differentiate as is necessary between the two main classes of stone which, according to their origin, are known as primary or secondary formation.

1. Primary Stones (Granite, Syenite, Diorite, Porphyry, Trachite, Basalt etc.).

The main constituents of these are known to be quartz and silicic bonding materials, styled silicates, such as feldspar, mica, hornblende, augite etc. The quartz may be considered as absolutely indestructible under atmospheric action; the silicates, also, show resistance to such an extent that even very small boulders or drifts, as encountered in the upper diluvial sand, have in a large number of instances remained practically unaltered.

But what an exposure to the action of the atmosphere lasting over centuries could not accomplish, has been effected in the course of geological periods by the agents at play in the earth's crust, therefore we find that the primary stones which occur nearer the surface have in many instances lost part of their original quality; the feldspar they contain has especially undergone a more or less serious transformation. When once this has commenced, it continues, as experience shows, at a comparatively rapid rate in the building stone when quarried and often leads in a very few score years to an extensive disintegration of the outer surface of the stone.

This leads to the following proposition:

The essential constituents of the primary stones may be considered to remain perfectly weather-proof during the whole of the time contemplated for the life of the building in which they are used, provided they have not undergone an extensive transformation previous to their being quarried.

This proposition is founded upon experience and is of the greatest importance for solving the problem, in that it affords a most simple method for testing stone of this class, which method resolves itself purely and simply in the determination of the original condition of the component parts of the stone, or, in other words, in the determination of the extent of weathering previously undergone by the stone. There is available for this purpose a generally most satisfactory method which is easy to follow, i. e. the microscopical examination of the stone in the form of thin transparent sections, using polarised light.

With regard to the strength of the texture of the primary rock formations, that is to say, the bonding of the grain by the crystallisation, this is generally so complete that on splitting up a freshly quarried stone, fracture is always across the granular components without the latter being disturbed from their former solidity. The crystalline bond resistance is, therefore, greater than, or at least equal to, the coherence of the granular components themselves; it disappears only with the disintegration of the latter.

The following general scheme for testing may now be put forward as applying to primary stone:

1. Microscopical research to ascertain the fresh condition of the component parts, or their degree of decomposition.

2. Determination of the resistance of the material forming the binding material of the grain, action of water and frost effect, in the case of stone the component parts of which are not absolutely undecomposed.

3. Quantitative analysis for determining an eventual percentage of ferruginous quartz. Estimation of the vitreous components present as to their basicity and percentage of iron.

2. Secondary Stones (Sandstone, Greywacke, Limestone, Roofing, Slates, Tufa, etc.).

For this class, weathering tests are of special importance inasmuch as it contains specimens of the most varied grades of quality. In the first place, and as regards the action of elements in the atmosphere upon the component parts of secondary stones, the durability of the grain and that of the binding materials can be considered together, for both substances are produced from the transformation of the primary formation and therefore both have, essentially, a similar composition. Where the transformation has been complete, there remain as residues which are not possible of further decomposition by the action of the atmosphere: quartz, amorphous silica, argillaceous and ophitic substances, calcium, magnesium and iron carbonate, iron oxide, iron hydroxide, together with the practically indecomposable mica. The imperfectly transformed material only, such as the small grains of half reduced feldspar and other silicates, also possible new formations, such as zeolitic substances, basic iron-silicates and ferruginous quartz, are subject to further chemical modification. The chemical decomposition of sedimentary stones therefore, is limited mainly to the reduction of these component parts also to the effect of ferruginous quartz and to the action of the gaseous products of combustion upon the carbonates. Microscopical research makes it possible to ascertain accurately the presence of such foreign materials.

The principal point for consideration in weathering tests with these stones is, however, their behaviour in regard to mechanical disintegrating action, as, for instance, softening by water and the effect of frost. The binding materials come preeminently into consideration in this connection; this consists generally of clay, marl, lime, iron oxides or hydroxides and in certain cases, of incompletely reduced fine particles of stone.

All these stony pulverulent substances have not in themselves any very great bonding power. If they come in contact with water, they form a kind of mud which hardens to a certain extent by drying; but since the connection of the granular matter is solely effected by adhesion it is sufficient for water to act afresh upon the mass to soften the substances down again and to cause them to be washed away when they occur in the stones.

These binding mediums, styled pelitomorpheous materials, acquire a stronger adhesion and a more complete cementing property only after a thorough mixing with such mineral substances as have separated from solutions in the stone, or which have been formed therein by chemical transformations. Among the authigeneous products, may be mentioned silica, in the form of quartz and opal; crystalline carbonate of lime; and, in certain instances, glauconite, iron silicate and zeolitic substances. When these infiltration products are lacking in the bonding material, the sedimentary rocks are always soft and can be disintegrated completely with water, while the stones are stronger and more resistant to the action of the atmosphere the higher the proportion of cementing authigeneous substances. In this case, microscopical research also affords a most satisfactory means for arriving at the relative proportions.

The following general testing scheme is applicable for a determination of the quality of sedimentary stones:

1. Microscopical research to ascertain

a) the mineralogical constitution of the granular constituents and the density of the binding medium;

b) the class of grain bond and binding substance;

c) the composition and structure of the binding substance;

d) the stratification and the pore formation.

2. Determination of the resistance of the grain bond and of the extent of softening by water.

3. Testing for resistance to frost by the determination of the coefficient of saturation, or by experimental freezing tests.

4. Chemical analysis to identify any components, which are difficult to classify in the mineralogical nomenclature.

Microscopical research appears to be of paramount importance in carrying out the tests above referred to, and the author

was able with the aid of lantern slides which reproduced a great number of sections, to illustrate the large field for the application of this method for technological research in regard to stone; the views showed the various textures which serve as standards for the determination of the durability of various types of stone.

Mr. **Cl. Segré** (Rome) presented the rules for the conduct of tests on the resistance of stones to frost adopted by the Istituto Sperimentale of the Italian State Railways, which, in view of the large use of stones on the Italian railway structures, play an important part. He further presented the Chairman with a study from the above named institute "Sur la détermination de la dureté et de la tenacité d'une roche compacte." (On the determination of the hardness and tenacity of a compact rock) in relation to rock-boring in connection with tunnel-works. He reported briefly on the tests for resistance to frost made by the Institute. The sample was first dried; then the air pumped out and water forced into it at a pressure of from 3 to 4 atmospheres. Hereupon it was put in a box and cooled by means of a solution of common salt down to a temperature of -15^0, in which it remained for about 3 hours; it was then left in a dwelling room temperature for the space of 5 minutes, after which it was immersed in a bath of $+35^0$. Three tests could be made in 24 hours. The building-stones must be able to withstand at least 40 alternations of temperature, from -15^0 to $+35^0$.

Prof. v. d. **Kloes** called attention to the great influence of the composition of the mortar on the weathering qualities of building-stones, and especially to the example of Cologne Cathedral, where the mortar used accelerates the weathering of these.

Prof. **J. Hirschwald** admitted that the mortar may be a partial cause of the weathering of the stones, and accordingly welcomed the resolution adopted on the previous day by the Section in regard to the appointment of a committee for the study of this question.

Prof. **J. Vogt** (Christiania) laid stress on the importance of the microscopic stone-investigations communicated by Geheimrat Hirschwald. We had here to do with a highly developed technique, which had been worked out in the course of several decades. The mechanico-technical testing-establishments would have to employ specialists in petrographic methods of work for the stone investi-

gations. The use of this method for the technical study of stones was still, he said, in its infancy.

The **Chairman** returned to the interrupted discussion of the previous day on the reports on plastic mortars, and on the hardening of Roman and Portland cements, and proposed the following resolution:

> "The Congress thanks Committee No. 42 for the "communications made, and invites it to proceed "further on the path entered upon, giving due regard "thereby to the results obtained by the Hungarian "Committee to which the Congress expresses its "warmest thanks. The Congress hopes that by the "meeting of the next Congress the Committee will "be able to present a definite method for the em-"ployment of plastic mortar in the testing of "cements."

This resolution was adopted.

Prof. **M. Gary** presented his report

"On the New German Standards for the Uniform Delivery and Testing of Portland Cement" ($XIII_5$).

These differ from the older ones in three important particulars.

1. The definition of Portland cement had been supplemented, by account being taken of its chemical composition. It must not have less than 1·7 parts by weight of lime and 1 part of soluble silicic acid + alumina + oxide of iron, and must be produced by fine pulverisation and intimate mixture of the raw materials, calcination at least to vitrification, and fine grinding. To this meal there may be added, for certain special purposes, not more than 3 per cent of other substances. The magnesium contained in it may at most amount to 5 per cent, and anhydride of sulphuric acid to $2^1/_2$ per cent.

2. The testing for tensile strength was given up, and in its place the requirements as regards compression-strength of the standard mortar and the fineness of grinding of the Portland cement were considerably increased. The speaker showed how it was proved by means of 30,000 distinct tests, that the reliability of the compression-test method was considerably superior to that of the

tensile test, and pointed out how greatly the tensile and compression tests vary in the table. He observed that the proportion between the two used to be taken at 1 : 10, whereas it had now been shown to vary between 1 : 6 and 1 : 15. The Portland cement must be ground so finely that on a 900 mesh sieve it leaves a residue of only 5%. The width of mesh of the sieve is not to exceed 0·222 mm.

3. The compression of cubes which have been exposed to the air for 1 day and have then lain for 6 days under water has been introduced, as the final standard test. Slowly setting Portland cement consisting of three parts by weight of standard sand and 1 part of cement shall attain a compression strength of at least 120 kgs. per sq. cm. After a further period of hardening of 21 days in the air the compression strength is to amount to 250 kgs. per sq. cm. The speaker moved that the Association decide to declare its adhesion to the German standard.

Dr. **O. Lieven** (Novorossissk) opposed the wording of the German standards, according to which the products were to be pulverised and mixed before calcination. As a result of this an Industry would be deprived of its possibility of existence. In Switzerland, Austria, the Balkan countries, South Russia, and the Caucasus there were a considerable number of marls which, when burnt without any previous preparation, gave an excellent Portland cement. It was not to be recommended, therefore, that the German standards be adopted for international conditions.

Dr. Ing. Rud. **Dyckerhoff** in reply contended that the text of the standards did not in any way prevent a cement, which was produced by the burning of a natural intimate mixture, from being accepted as a Portland cement.

Prof. **M. Gary** considered that the definition of the German standards given was adapted to the German conditions. In Germany natural cements of the kind referred to did not occur.

President **Grut** stated that Mr. **Rich. L. Humphrey** (Philadelphia) proposed the following resolution:

> "The Congress wishes that a Committee investigate the question as to whether it is possible to "adopt an international standard sand, and, should

"this not be the case, to collect results of experience "on the relative values of the various kinds of "standard sand from the different countries."

Mr. **Rich. L. Humphrey** gave reasons in support of his motion, but said he did not believe that it would be possible to come to an agreement with reference to an international standard sand. He was of opinion, however, that it would be of great importance to obtain information in regard to the standard sands of the different countries; in recent years so many different standard sands had made their appearance, that comparative experiments had become necessary.

A second motion, that a committee be appointed to study the question of a unification of the methods of testing hydraulic cements, was, on receipt of an explanation, withdrawn by Mr. Humphrey.

Prof. **F. Schüle** pointed out that the Bauschinger Committee had already given its attention to this question, and that in going into the question of a uniform method of testing cements Committee Nr. 42 would also be handling that of standard sand.

Prof. N. **Belelubsky** advised that caution be exercised in the appointment of committees. The Bauschinger Committee had some time since shown, how a universal standard sand might be obtained.

The **Chairman** put to the vote the Humphrey motion, which was adopted. Since, however, the Chairman was reminded on several sides that Committee No. 42 had already been entrusted with the treatment of the question of standard sand, he declared that, in informing the President of the Association of this Sectional Resolution, he would also communicate this circumstance to him.

Finally Prof. **M. Gary** withdrew his motion in regard to the German standards.

The **Chairman** passed to the discussion of the Committee Report

"On Accelerated Tests of the Constancy of Volume of Cements" (X_3)

Mr. **Bertram Blount** (London) submitted the report in question and stated that he had come to an agreement with several members of the Committee upon the following wording regarding the Le Chatelier tests, which he proposed for acceptance:

"The cement is mixed and put into a mould which is placed "upon a glass plate, the points of the indicator needles being held "together. When the mould is filled, it is covered by another glass "plate held down by a small weight. The whole is immersed for "twenty-four hours in water at 15° C. (59° Fahr.). The ties or "other devices used to hold the mould together during the setting "are then removed; the distance between the needles is then "measured and the mould is placed in cold-water which is brought "to boiling point within one hour and is maintained boiling during "six hours. The mould is then taken out of the water and after "it has cooled down the distance between the needles is then "measured afresh. The difference between the two readings represents "the expansion of the cement."

This motion was opposed by several of the German members, who pointed out that in England itself the method was not introduced until it had been decided to expose the cement to be dealt with to the air for a certain length of time before the beginning of the test. This however rendered the test of no value, since cements of inconstant volume soon became constant when exposed to the air and ceased to swell.

Dr **Dyckerhoff** (Amöneburg), opposed the motion of the Committee and he added: "The Association of German Portland Cement Manufacturers, considering the results obtained from a series of tests of considerable length made by a committee of the Association in connection with the Royal Laboratory for the Testing of Materials, Gr.-Lichterfelde, is of opinion that the cold-water test after 28 days is completely reliable, for the formation of judgement as to the constancy of volume of a cement, and that the Le Chatelier accelerated process proposed by Committee No. 32 for adoption, consisting in the boiling of the cement sample after it has been hardened for 24 hours under water and the measurement of the extension in the Le Chatelier mould, is not to be recommended."

Expression was likewise given some time ago in Germany to the view that the cold-water test after 28 days was not sufficient; hence it was that the above-named committee was appointed. The Royal Laboratory obtained 10 cements in the market and distributed them among the members of the committee. The cold-water test and several accelerated tests were then made. All the cements withstood the "cold-water test after 28 days"; the accelerated

tests, as also the cake test made by boiling after 24 hours hardening, ended in the failure of some of the cements. In addition, in the case of all the cements, strength-tests were made on mortars of 1 : 1, and 1 : 3, made after hardening periods ranging up to 2 years. The cements which had failed to withstand the accelerated tests here behaved in an entirely normal manner.

That a cement failed to withstand the hot water test merely showed that the cake which had been exposed to the action of boiling water after a hardening period of 24 hours and had thereby developed cracks, was at such a stage of hardening that it was not yet able to withstand extension produced by the accelerated hydratation due to the higher temperature. Since, further, cement cakes that had behaved well under the cold-water test and developed cracks after periods of 24 hours hardening, were able to withstand the boiling after hardening in water for some days or weeks, it followed that such cements do not contain any of the so-called detrimental lime and would therefore give good a account of themselves in practice.

This view was supported by the test-results of the above named committee, which also conducted tests under conditions corresponding with those of actual practice. With all the 10 kinds of Portland cement, rosettes, medallions, and drain covers were made by a cement-works from an intentionally rich mixture of 1 of cement to 1 of sand. After undergoing periods of hardening of 3 days and 4 weeks respectively in the workshop, these were exposed to all the influences of the weather. After a period two years of observation the objects showed a few small unimportant edge-cracks, and fine hair-cracks, which however were to be attributed to shrinkage caused by the rapid drying of the rich layers of cement pulp. Apart from this, all the objects were well hardened and in good condition, although some of the cements used had failed to withstand the boiling test.

All the cements had likewise successfully withstood the cold-water test; in respect to the boiling, however, some of the samples which had failed under it, had been falsely judged. It had moreover also been shown at the International Congress in Zürich, that some cements which under the boiling test showed themselves to be unexceptionable had failed under the cold-water test.

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The speaker pointed to the conclusions from the tests in question advanced in the "Mitteilungen des königlichen Materialprüfungsamtes" (Communications from the Royal Laboratory) in Berlin, Supplement No. 1, which were to the effect, that none of the so-called accelerated constancy-of-volume tests were well suited in all cases to serve as bases for the rapid formation of a reliable judgement on the admissibility of a cement for use in actual practice. The tests have further shown that all the 10 cements then experimented with, which withstood the standard cake-test are also constant in volume (in the practical sense) when given the form of test samples or cement wares of commerce. The increase of strength of the test samples during the processes of hardening in water and air speaks for the applicability of the cements in practice.

The objects referred to, which were kept for 10 years on a roof, are now, for further observation, in the Gr.-Lichterfelde Laboratory, exposed to all the influences of the weather, and are after 12 years, still in good condition.

The Le Chatelier method recommended by Committee Nr. 32 for accelerated tests of cements for constancy of volume corresponds in principle to the so-called boiling test. In both cases the cement, hardened for 24 hours, was exposed to the action of the boiling water. Under the boiling test the more or less considerable crack-formation was observed on examination of the cakes, while by the Le Chatelier method the extension produced by the formation of the cracks was measured. The last mentioned test is the more exact, and depends less on the judgement of the operator. Le Chatelier's test, however, is, equally with the so-called boiling test, unsuitable for the above mentioned reasons for the formation of final decisions as to constancy of volume, and the speaker was informed that the German Portland Cement Manufacturers in consequence considered it necessary that the "cold water test after 28 days" be retained as the deciding one, until a constancy of volume test can be discovered which enables tests to be reliably carried out in a shorter time than by its use.

In the new German standards also, the cake test in cold water hitherto applied was therefore retained as the deciding one for constancy of volume. The speaker declared, however, that the German members were quite willing to co-operate further in the labours of Committee Nr. 32.

In conclusion he further wished to point out that, according to Committee Nr. 32, under the Le Chatelier test an exposure to the air of the cement to be tested after 24 hours and 7 days respectively is also provided for. A cement which fails under the Le Chatelier test immediately on delivery, may very well be able to withstand it after 7 days exposure to the air, and in his opinion the cement must therefore be tested as it is delivered.

Mr. **B. Blount** stated that he knew the German cements quite well for he had had much to do with them, and if they could not stand the hot-water test, he would contest their constancy of volume.

Prof. **D. v. Nagy** (Budapest), laid emphasis upon the necessity of deciding the point after the lapse of seven days. He called attention to three causes which made for expansion of cements, the action of the hydrated sulphate of lime, that of magnesia and that of lime. The contents of hydrated sulphate of lime and of magnesia could be ascertained by analysis, but the point as to whether the lime content was too high could not be determined by an analysis. The free lime unslacked in water was specially dangerous. He agreed to the motion before the meeting.

Mr. **E. Leduc** (Paris), recommended the Committee's decision. He considered the Le Chatelier test a very satisfactory one, especially for rotary-kiln cements as was proved by numerous experiments.

Mr. **Mayntz-Petersen** (Copenhagen) was also in favour of the Committe's proposal.

Dr. **P. Prüssing** protested against Mr. Blount's statement to the effect that the test was a too severe one for the German cements. He (the speaker) had already taken part in the discussion on the hot-water test at the former Congress and had shown a cement which had satisfactorily withstood that test, but which was not constant in volume. He considered the Prüssing cake-pressure test as a much more severe test for many cements and more suitable for every day practice. Some cements were made with but very little water, for use for ornamental stone manufacture, which, later on, were subjected to the action of large bodies of water. In such cases many cements failed which had satisfactorily undergone the hot-water test.

Mr. **B. Blount** believed that Dr. Prüssing's cements satisfactorily stood the Le Chatelier test; should they not do so, he

could not, he was sorry to add, consider them as being constant in volume.

Dr. Rud. **Dyckerhoff** remarked that cements rich in lime withstood the hot-water test very satisfactorily.

Prof. **D. v. Nagy** (Budapest) was of opinion that the strength of cement increased during the hot-water tests and that by maintaining the cement for six hours in boiling water a strength was reached equal to that obtained after twenty-eight days in the open.

Mr. **Rich. L. Humphrey** (Philadelphia) regretted that no reference was made in the motion with regard to the quality of the water. The water available throughout America varied greatly in composition from one place to another and the class of water used had a very great influence upon the tests. He considered as very doubtful whether the complicated Le Chatelier method could be recommended for general application and expressed the hope that a more satisfactory test would be decided upon later.

Mr. **B. Blount** was of opinion that in all parts where cements would be required to be tested, water sufficiently clean for drinking purposes could be obtained, and all drinking water was sufficiently good to be used for carrying out the tests. The Le Chatelier test had been introduced in England several years ago. This fact afforded a proof that it was not too complicated; it could be carried out almost by anybody.

The following resolution was thereupon adopted by forty-seven members, there being nineteen dissentients:

> "The Congress resolves that the Le Chatelier "method be recommended as the standard accelerated "test for the constancy of volume of cement."

The German members entered formal protest in the minutes against this resolution.

The **Chairman** passed on to the discussion of the report.

On the Best Manner of determining the Commencement and the Time of Setting (X_{11}).

Mr. **I. Laborbe** (Paris) presented his report on the use of the ball-pressure test for the determination of the time of setting. He showed a series of tests which he had made with his apparatus, and referred to the diagrams which illustrate the test procedure.

Mr. **E. Leduc** (Paris) recommended the Laborbe apparatus, with which he had himself obtained satisfactory results.

President **Grut** thanked Mr. Laborbe for his interesting report and adjourned the discussion of the questions still remaining until Saturday morning.

4th Meeting, Saturday, September 11th, 1909.

Capt. **Grut** invited Prof. Gary to present his report:

"Determination of the Simplest Method for the Separation of the finest Particles in Portland Cement by Liquid and Air Process" (X_7).

Prof. **M. Gary** referred to the report delivered partly by himself and partly by Mr. Mayntz-Petersen. The Committee some days ago held a meeting and decided — since proposals pointing in two directions had been made, as to the manner in which this process can be applied to the purposes of scientific investigation — to propose to the Congress that they be empowered to continue their labours.

Mr. **Mayntz-Petersen** (Copenhagen) would like, in the first place to call in question the statement made by Prof. Gary in his report, "that the Petersen apparatus can take the place only of a sieve finer than 5000 meshes per sq. cm., and divides the cement for testing, only into two portions (fine and coarse meal), so that the tests on different cements with sizes of grain evidently differing considerably, show only small differences there being thus no advantage over the separation by a 5000 mesh sieve." The speaker further remarked that this cannot constitute an objection to his apparatus, since to a considerable degree a similarity between sifting and bolting must of course exist, which may also be seen from the Prof. Gary's results, especially when, in order to compare these with the speaker's, the sum of the different grain sizes (I + II, I + II + III) are set off graphically.

He further observed that, in his experiments referred to, he only used one bolting hopper, with which the residue was approximately 50%. But he could make the bolting hopper of such dimensions that the residue was greater, so that the separation could take place for other sizes of grain. Further several hoppers

can be used when it is desired to test the fine meal more thoroughly. He made a brief reference to the experiments which have been begun in the State Laboratory, Copenhagen, at the cost of the Association of Scandinavian Portland Cement Manufacturers[1]) on the influence of grinding on the size of grain and other qualities of cement. At these experiments two bolting hoppers are made use of: in the second of these the lower opening is somewhat smaller, as a result of which a larger residue remains behind. If, now, first the per cent amount of the residue on the 5000 mesh sieve, and then the amount of the residues on the first and second hoppers be determined, we have, first, the $^0/_0$ of residue at the hopper; secondly, the difference between the second and first figures; thirdly, the difference between the third figure and the second, and finally the percentage figure required to make up 100, or an exact classification of the cement in four sizes of grain. In view of the lateness of the hour, the speaker did not wish to go further into the results obtained. In conclusion he believed himself justified in asserting that, as compared with the Gary apparatus, his own had the advantage of greater simplicity, and that, in connection with the latter, it was possible without difficulty to adjust several hoppers in such a manner that they gave the same result, and that the possibility of providing several bolting hoppers enabled several divisions with residues up to $70^0/_0$ to be made. For the rest the speaker supported the motion of Prof. Gary.

President **Grut** moved the following resolution:

> "The Congress begs Committee 30 to continue
> "their work on the adopted lines and to report on
> "the results at the next Congress"

which was adopted by the meeting.

In reference to the report

"Unification of Specifications for Gypsum" (X_9).

Prof. **M. Gary** stated that he had communicated with Mr. Feret in regard to the question: Both reporters recognised that this difficult question admitted of no satisfactory solution at present. The speaker had received a letter from Mr. Sátori Mór, of Budapest,

1) A report on all the experiments undertaken will at a later date be published.

in which the latter expressed the hope that the German Gypsum Association might, by the time of the meeting of the next congress, be in a position to provide data for the solution of this question.

The Chairman proposed to postpone the treatment of the question till the next Congress, which was agreed to.

He then passed to the discussion of Report:

"Testing Puzzolanas with the object of determining their Value for Mortars" (X_{10}).

Mr. **G. Herfeldt** (Andernach-on-the-Rhine) gave a resumé of his report. He was sorry that the participation in the work of the committee had been so small, and laid stress on the difficulties which had cropped up among its members in coming to an agreement. Thus differences of opinion occurred even on the question, as to the form — whether powder or paste — in which the lime should be used in the tests. In the countries in which Puzzolanes are used in large quantities, as for instance in Germany, Italy, Holland, and Belgium, exact methods of testing are prescribed, which, though differing from one another, completely attain their objects, since, when made with the same materials and by good operators, they thoroughly suffice for determinating the values of the various puzzolanas. In the face of these old-established methods the problem of the establishment of uniform rules appeared hopeless. To this was added a circumstance which almost prevented the establishment of a uniform system of testing, viz., the different methods of application of the Puzzolanas. In Germany, Holland, and Belgium, only one method of application of the Puzzolanas. — i. e. that in which they are ground as finely as possible — is known, while in Italy only the crude Puzzolanas in the loose condition in which they occur are made use of. The speaker referred to the work which Mr. Feret presented to the VII. Congress for Applied Chemistry in London 1909, and in which he proposed to determine the value of the Puzzolanas by series of chemical tests. On the basis of a discussion which he had had with several members of the Committee, the speaker wished to move the following:

"Committee No. 11 is commissioned to collect the standards "prescribed for the testing of Puzzolanas in the different countries,

"and to bring them to the notice of the members of the International "Association. The Congress is of opinion that, owing to the use "of different kinds of lime and sand, and of puzzolanas either "ground or unground (pouzzolanes à l'état granulaire) a uniform "method for the different countries cannot give results that admit "of comparison one with another, and is for this reason impracticable".

Mr. **Cl. Segré** informed the meeting that the Italian Association some years ago appointed a committee to lay down rules for the testing of Puzzolanas, immense deposits of which occur in Central and Southern Italy. The speaker paid grateful tribute to the service rendered by Mr. Feret in connection with the work of Committee Nr. 11 of the International Association. The question entrusted to the Committee was still at the same point as at the time of the raising of the question in Zürich, and at the time of the proposal he made in Brussels in 1906, to the effect that a distinction be made between the standard methods of testing trass and those of testing Puzzolanas in the unground condition. Although both materials are of the same origin and though both these volcanic products are of a puzzolanic nature, in so far as they have to be mixed with lime in order to produce hydraulic mortar, they nevertheless require different tests, however much they have in common with each other. On the other hand the testing methods must not diverge too much from the ordinary ones of the materials in general use. This was the reason why no agreement had been come to in regard to methods of testing. But the labours of the committee on the Puzzolana question were of a general character and had been exceedingly useful, especially for the Italian Association. He was of opinion, then, that two kinds of rules were necessary:

1. Rules for puzzolanas which in their natural condition are compact and which can be pulverised artificially for use.

2. Rules for puzzolanas in unground condition which are applied in the state in which they are found in the deposits. The speaker presented the report of the "Istituto Sperimentale" of the Italian State Railways, which contains an extract from the rules for true puzzolanas (pouzzolanes granulaires), which were laid before the Italian Testing Congress of 1907 in Rome and since then have in the light of investigation and experience been extended for putting before to the Congress of Palermo in 1910. In conclusion he observed that these rules had already been in use for

20 years with very satisfactory results in the laboratory of the Italian State Railways, where they have been uniformly and strictly applied.

Mr. **M. Rózsa** (Budapest) referred to some of the proposals of Committee Nr. 11. He advocated that standard tests be made either with lime paste or with slaked lime in powder, but that slaked lime in paste be dried till the hygroskopic water evaporates, then reduced to such a degree of fineness that the pulverised hydrate will pass through the 5000-mesh sieve. As a degree of fineness of grinding for the standard tests, he proposed that laid down for the Portland cements. In opposition to the view expressed by Mr. Herfeldt, he had found that the stony compact parts of the trass were the best ones, and contained silicic acid having good binding qualities, and that a large number of tests had shown that the strength increases with the fineness of grinding just as in the case of other cements. He recommended that the addition of the hydrate of lime should always bear a certain proportion to the binding silicic acid, and that this latter be determined by dissolution in a 20% solution of hydroxide of potassium. Finally he recommended that test samples intended to be kept for a time in water should not be immersed in the latter tili 48 hours after their preparation, since it was often found that the trass-mortar had not yet become set. Tensile tests should be made after 7 and 28 days, and compression tests after 14 and 28 days exposure to water or to a damp atmosphere.

At the conclusion of Mr. Rózsa's remarks the Chairman moved that the question of the testing of puzzolanas as to their value as mortars be adjourned till the next Congress, because the time was already so far advanced that the meeting must be closed, and a discussion on the different, and, partly, diametrically opposed views was no longer possible.

The following resolution was accordingly adopted:

> "The Congress leaves the question of the tes-
> "ting of puzzolanas to the next Congress."

Mr. **Mayntz-Petersen** (Copenhagen) submitted his proposal for the alteration of the method of cement-testing recommended by the Brussels Congress, since the quantities of cement-mortar prescribed therein were too small to fill the mould.

The **Chairman** made the proposal that the resolution take the following form, which was also agreed to:

> "The Congress gives to § 3 c) of the method "recommended by the Brussels Congress for the "testing of puzzolanas the following new wording:
>
> "A conical metal ring the lower diameter of "which is 7·5 cm and the upper one 8·5 cm and the "depth of which is 4 cm and which is mounted on a "plate of glass, is to be at once filled with the "already mixed paste. The upper surface is then to "be smoothed off with a knife, all settling and "shaking being meanwhile avoided."

The **Chairman** closed the proceedings and thanked the participators in the work for their contributions and also for the active part taken by them in the discussions.

Prof. **Gary** conveyed the warmest thanks of the meeting to Captain Grut for the masterly way in which be had conducted the proceedings, his words being accompanied by the loud applause of those present.

Conclusion of the meeting at 10.0 a. m.

Proceedings of Section C (Sundries).

First Day's Proceedings. Wednesday, Sept. 8th, 1909.

Prof. **A. Mesnager** opened the Meeting. He read the names of the Honorary Presidents and Honorary Secretaries of Section C and requested the Chairman Commander **Münter** to undertake the conduct of the proceedings.

The Chairman Commander **B. Münter** (Copenhagen) first addressed himself in warm words of welcome to the specialists who had responded to the call to Copenhagen. In regard to the problems dealt with by Section C, Commander Münter continued, they were, in comparison with those of the other sections, much less numerous and less beset with difficulties. But this very circumstance would enable members to give their special attention to the reports; all who have read them will acknowledge them to be worthy of it. Commander Münter concluded with the hope that the meeting might be able to add an instructive and useful supplement to the reports which had already achieved so much, not only from the industrial point of view, but also from that of the general community. The International Association had moved vigorously forwards. Within a short time it had succeeded in creating a new science devoted to practical aims, and in so doing it had understood how to make a skilful use of other branches of knowledge, including pure theory.

After these observations the Chairman opened the discussion on Paints on Metallic Structures with the report

"On the Corrosion of Iron in Water and Aqueous Solutions" ($XVII_1$).

He called on Prof. E. Heyn.

Prof. **E. Heyn** (Gr.-Lichterfelde) gave a short review of the work carried out by himself and Prof. O. Bauer, which had

been published in the Communications. He stated that the important factors in rust formation were flowing water and oxygen dissolved in the water

The presence of carbonic acid, he said, was not necessary for the formation of rust; this acid acted as a dissolvent like every other. The rapidity of rusting and of the consumption of oxygen connected therewith depended above all on the supply of oxygen.

Prof. E. Heyn mentioned all the circumstances which exercise influence on the concentration of the oxygen in the vicinity of the rusting iron, such as the distance between the surface of the iron, the area of the surface of the liquids by which the oxygen diffuses, the supply of fresh air, the increase of the partial pressure of the oxygen in the atmosphere in contact with the liquid; the renewal of the liquid, and the proportion borne by the quantity of liquid to the surface of the iron. He said that a part is also played by the smaller solubility of the nitrogen compared with that of the oxygen, so that, when a liquid saturated with air is heated, a mixture rich in oxygen is given off. If this collect in the form of air-pockets on the parts of the iron under-water, as for instance in a steam boiler under pressure, two rust-causing circumstances act together: — the enhanced partial pressure of the oxygen and the increased percentage of oxygen in the gas.

The speaker then gave an account of the tests, which were made to determine, whether, in case of faulty coating, an attack of rust can take place in the inside of a gasometer at the point where the plates of the receptacle dip into the water-tank. This proved to be possible, because the oxygen of the atmosphere is capable of diffusing itself through the protecting water of the receptacle to the iron. The means of preventing corrosion, Prof. Heyn added, correspond with those for the prevention of the presence of the pressure of a percentage of oxygen in the water. The covering of the surface with oil is inefficacious, because oil has a greater capacity than water for the absorption of oxygen. The suspension in the water of bags filled with charcoal-powder is more successful. Prof. Heyn then discussed in detail the influence of contact between the iron and other metals on the attack in water. By the contact of the iron with a less precious metal in the electric tension scale the attack of the rust on the precious metal is diminished and that on the non-precious one is increased.

When iron comes in contact with a more precious metal, the former is attacked in an increased degree through the medium of aqueous rust-producing solutions Similarly, by contact with zinc, iron is found to be preserved from rust, while, on the other hand, its oxidation is increased by contact with copper or nickel. Mild steel may, under certain conditions, be protected by a contact with cast-iron. The order of the metals in the tension scale is not invariable as regards their electric properties, but depends on the fluid in which these are immersed.

The question, what kind of iron (wrought-iron, mild steel, or cast-iron) exhibits the greatest tendency to the formation of rust, is still an open one. In an experiment in undisturbed distilled water, for instance, it was found that: after a lapse of 2 months, mild steel was attacked most, wrought-iron to a less, and cast-iron to the least, degree; after 7 months cast-iron was attacked most and mild steel least, while after 17 months mild steel and cast-iron were attacked in almost equal degree. On a resumption of the tests, the conditions may happen to be different, so that it may be partly matter of accident which kind of iron will, after a given duration of the test, show the greatest or least degree of attack. The differences in all these cases, however, are very small, and in presence of the other influences play quite a minor part. The statement that the solubility of the materials in sulphuric acid supplies a measure for the degree of attack by rust, is not correct.

Prof. Heyn then discussed the tests for the determination of the corrosive power of various fluids on iron, and explained the conceptions of critical concentration and limited concentration of a solution. The view that the alkaline solutions in all cases prevent the attacks of rust, is wrong. The protective action of the carbonates of alkali shows itself only in certain combinations. Below this concentration there may exist solutions which, in part, produce very strong attacks. Equally wrong is it, that chlorides and alkaline sulphates in every case produce stronger attacks than pure water. Chromic acid and its salts are the powerful protectives against rust. Even small additions of these chemicals to distilled water have a protective effect.

The speaker saw an interesting posibility for the explanation of the complex phenomena of oxidation in the study of the fall

of electric tension between iron and the various fluids. Professor Heyn finally gave some hitherto unpublished particulars of tests which were made for the purpose of clearing up the influence of the temperature on the formation of rust. It had transpired, in connection with these, that for distilled water the maximum of attack lay at about 60^0. From this point to about 100^0 the corrosive power fell again, till it reached a minimum at the later temperature. At ordinary temperature the attack was only about $^1/_4$ of the maximum.

Mr. **E. Camerman** (Brussels) declared Prof. Heyn's theoretical comparisons to be of the greatest value in actual practice. He asked whether Prof. Heyn agreed with some practical conclusions which he himself had drawn from the feed of steam boilers. Prof. Heyn, he said had directed attention to the importance of the electrolitical processes. This influence was further increased when the conductivity of the liquid medium was increased by the presence of certain salts — in particular of sulphate of sodium. He inferred from this that it was necessary, in analyses of water, to pay attention not only to those which remain in solution, but also to the ones which, by reason of the escape of the steam, become more and more concentrated. Under certain cicumstances these salts may become powerful electrolytes; their detrimental iufluence shows itself in particular in certain locomotive boilers at the point where the copper tube-plate is connected with the iron plate by iron rivets. The heads of such rivets are prematurely attacked by the oxygen set free.

The sulphate of sodium owed its formation principally to the introduction of the scale-preventing sodium-based products of the combination of the sulphates of lime and sodium.

Prof. **E. Heyn** (Gr. Lichterfelde) admitted that the action of galvanic chains formed by the contact of different metals in the elektrolytic solutions was increased by the growth and conductibility, and therefore by the increase of the percentage of salts in the solution. It was, hovewer, to be observed that, after the removal of the salts from the water, so far as this is practicable (distilled water), the galvanic action still remained. Even in distilled water the contact between different metals had a considerable influence on the attacks made by rust.

There were two means of diminishing the attack:

a) Reduction of the conductivity of the solution (i. e. the use of water of the greatest possible purity);

b) Reduction of the percentage of oxygen present in the solution.

The former of these diminished the galvanic action only to a certain degree, while it, on the other hand, considerably increased the attack of the rust on the iron, because pure water possessed the maximum of capacity for the dissolution of oxygen. Thus, one evil was removed by another one which was at least as great. Prof. Heyn believed that good practical results can be obtained by the use of the means a) only in a very restricted number of cases.

The means b) was at any rate the more effective of the two, because, after the de-oxygenation, all rusting ceased, including that produced by galvanic action. Every diminution of the percentage of oxygen in the solution corresponds with an increase in the life of the particles of iron in relation to the attacks of rust. In practice the greatest attention will have to be paid to all circumstances which have the effect of mechanically mixing air with the water, since every air-bubble acts like a store of oxygen, by means of which the water can keep itself saturated with this element.

Mr. **E. Camerman** (Brussels) said, in reference to the interesting study on the influence exercised by the air and carbonic acid set free in water from the solution, in regard to which Prof. Heyn had reported, that it is a well-known circumstance that, at the points at which the feed water is introduced into a boiler, the plating of the latter is attacked by patches of rust, and that hydroxydes of iron show themselves there in the form of blisters. In locomotive boilers, for instance, there are anchor-rods which connect the two copper tube-plates with one another. These become covered with rust exactly above the point at which the water enters the boiler. Oxygen is introduced by the cold water. The little oxygen bubbles which appear on the upper surfaces of the anchor-rods remain in contact with the iron and destroy the metal. The little bubbles which appear on the lower, or on the side, surfaces, are quickly expelled and replaced by large ones which rise from the bottom and which even, though they do not settle on the iron, always remain separated from it by an extremely fine layer of water. These little lower and lateral air-bubbles do

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not develop any rust, while the large bubbles which cover the upper surface scoop out the iron and very appreciably reduce the sectional area of the anchor-rod.

It would be interesting to find a remedy for this evil, whether in the form of a protective like one of the tar-products won from non-acidous minerals, or whether in that of an arrangement by which the air and the carbonic acid are enabled to escape at a place at which no danger is to be apprehended.

Prof. **E. Heyn** supplemented the remarks of Mr. Camerman by a few observations from actual practice, which he briefly illustrated by means of hand sketches.

Mr. **A. Grittner** (Budapest) observed in relation to Prof. Heyn's report, that the corrosion of the gasometer dome is to be attributed only to the circumstance that the air is diffused in the trap water; even if it should become possible to avoid this circumstance, the inside of the receptacle would rust, since the gas is washed by the water in the scrubbers and thereby absorbs air.

The speaker further reported on the tests conducted by him, which proved that rusting cannot take place without carbonic acid. An experiment which lasted for three months, in which oxygen which had been carefully freed of carbonic acid was led over polished iron, had shown that no rusting takes place. Finally, at the conclusion of the experiment, the apparatus was removed, and corrosion began in a quarter of an hour. The part here played by the carbonic acid was merely that of initiating the reaction, which, in the presence of oxygen, then continued.

In the case of locomotive boilers which are fed with alkaline water the iron never rusts, but on the other hand the fire-box, stay-bolts, and stay-tubes, which are of copper, are severely attacked. Experiments have shown that the soda of the alkaline feed water, when subject to a pressure of 10 to 12 atmospheres, is partly transformed into soda-lye, which attacks the copper. These circumstances prove that, under the influence of pressure, soda can prevent rusting.

Prof. **E. Heyn** answered that he must admit the possibility that the attack of the gasometer by rust might also be ascribable to the circumstance that gas had carried air along with it, for instance from the scrubbers. Prof. Heyn agreed with Mr. Grittner on the point that a solution of 4 to 5 kgs. of soda per m^3 of water does

not attack iron. In regard to the rust formation due to the influence of carbonic acid, as observed by Mr. Grittner, the speaker could not speak definitely, since he was not possessed of exact knowledge of the arrangements of the experiments in question; it might happen that the explanation could be found in these. At any rate the experience of Mr. Grittner contradicted all the observations which had been made in Gr.-Lichterfelde, all of these comfirming the proposition that the presence of carbonic acid is not a necessary condition for the formation of rust. He suggested that Mr. Grittner write down exactly the procedure followed in the experiment, so that it may be possible to check the results obtained with it.

Commander **B. Münter** here interrupted the discussion on the means for the prevention of rust, and adjourned the meeting till next day.

2nd Day's Meeting, September 9th, 1909.

Commander **B. Münter** opened the meeting at 9.30 a. m., and invited those present to continue the discussion on the means for the prevention of rust.

He first called on Mr. **E. Camerman** to speak on his report:

"A study of Rust-Preventing Points for Metal Structures" ($XVII_3$).

Mr. **E. Camerman** gave a brief summary of the contents of his report and of the studies discussed therein. In the course of his investigations Mr. Camerman had arrived at the following results:

The paint to be used must consist of iron-minium which, to the exclusion of essence of turpentine, is to be stirred in boiled linseed oil. The determination of the amount of dryer to be added is to be left to the judgment of the man in charge of the work.

Good results are likewise obtained if greater or smaller amounts of iron-minium are replaced by graphite. In this case the graphite must be pulverised to an extremely fine degree and must contain at least 55% of carbon.

The determination of the amount of paint-powder to be stirred up with the linseed oil may be left to the discretion of the workman.

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Mr. **P. Decamps** (Brussels) desired that the question as to the effect of galvanising and tinning as a protection against rust be more exactly determined by experiment, and made a proposal in this sense, on the strength of which a resolution was adopted as follows:

"The question of galvanising not yet having been "studied in the reports, the Congres desires to have "researches made as to galvanising and also to tin "coating."

Mr. **A. Grittner** said he would like to supplement the experiments and observations made by Mr. Camerman with the results of his own experiments, in connection with which he stated that these latter were conducted in the open. The results of the experiments were summarised by the speaker as follows:

1. Both the dryer and the turpentine exercised a detrimental influence on the durability of the coating. The greater damage was done by the dryers, which are made almost entirely of resinous substances.

2. The use of lithopone did not prove satisfactory in the open air. The coating developed cracks, and within a short time showed signs of weathering. Whether this weathering is a result of the oxidation of sulphide of zinc to sulphate of zinc, is a matter which should be investigated.

3. Those colouring substances which form chemical combinations with linseed oil or oil-varnish, and take the forms of lead minium and litharge, behaved very well.

4. It was a fact, that iron-minium, when pure and applied alone, gives very good results; when, however, another coat of paint is spread over it the extent of which is different from its own, it does not behave so well as lead-minium.

5. A paint should never be examined alone, but different groundings should be covered by different second coatings, and the effects observed.

Mr. **P. Joosting** (Utrecht) said that several experiments made in Holland have shown climatic influences to have a great deal to do with the durability of a paint. Thus, for instance, the observation of Mr. Camerman, that iron-minium is better than lead-minium is not universally correct. Experiments made in Hol-

land, at any rate, have proved that iron-minium is unsuitable as a second coating, for after the lapse of two years, it was completely spoilt.

Mr. **E. Camerman** replied, that the cause of the spoiling perhaps lay in the dryer made use of, or perhaps in the circumstance that the iron-minium applied was not pure.

Since Mr. Cruikshank Smith (London) and Mr. S. S. Voorhees (Washington) had not arrived, the Chairman, Commander Münier gave a brief summary of the work of these gentlemen, which was included in the "Communications" and comprised Mr. J. Cruikshank Smith's report:

"A plea for International Investigation concerning Protective Coatings for Iron and Steel" ($XVII_4$)

and Mr. S. S. Voorhees' report

"On Preservative Coatings for Iron and Steel" ($XVII_2$).

Mr. **E. Camerman** thought it would be desirable to have a committee for the study of the question of coatings for protection against rust.

The Chairman desired Mr. Camerman to undertake the direction of the discussions, and proceeded to speak on the papers; he referred to the great importance attaching to the examination of the coating material which in particular was applied to the bottoms of iron vessels. Commander Münter called attention to the special circumstances which exercise influence in connection with the use of iron in reinforced concrete, and proposed a resolution which was adopted in the following form:

> "The Congress considers it highly desirable that
> "special attention be given to the question of keep-
> "ing clean the bottom of iron and steel ships, and
> "requested the Council to have this most important
> "question investigated. (Accepted.)"

Oils.

Mr. **E. Camerman** (Brussels) demonstrated, on the basis of theoretical considerations, that, in regard to their chemical and physical properties, cylinder oils are very much alike, and that if any great differences existed between them, they depended

on the quantity of oil which remained fluid at the temperature prevailing in the cylinder, and which was not easily made to take the form of steam.

For the determination of the absolute value of an oil the speaker made use of a distilling apparatus in which the temperature gradually rises and the oil is carried away by the superheated steam.

In this distilling apparatus, as in all others, its own form, and dimensions, as well as, above all, the operator himself, exercised great influence on the final result of the experiment.

The steam generated in a boiler A is superheated in B and acts on the oil which is contained in a flask that is also heated.

The oil is carried away by the steam at a higher or lower temperature according to its nature. The point is observed when this process begins, and from this time forward a mixture of oil and water is collected at the end of a cooling apparatus in a graduated tube in which separation takes place by reason of the difference in density.

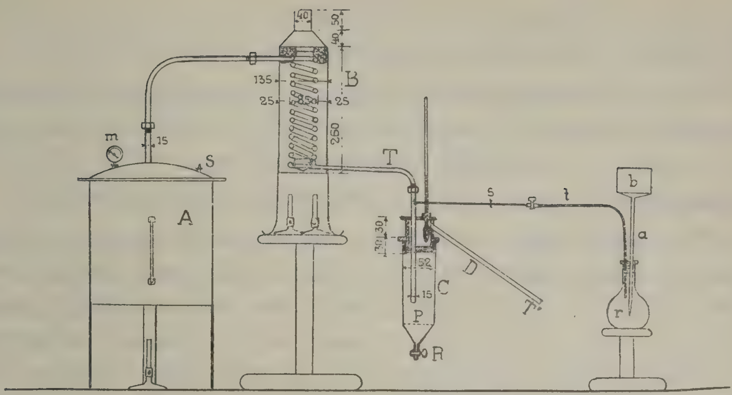
In this way the successive fractions — for instance from 10 to 10^0 — can be obtained, and a table may be put together which gives the quantity of oil carried away by the steam at each temperature. From this the quantity of the unvolatilised and therefore still effective oil at any given temperature may be determined.

It is clear that an oil containing $80\,^0/_0$ of stable components is of greater value for cylinder lubrication than one containing only $40\,^0/_0$. The observations of practical men confirm this.

This apparatus has the disadvantage that it gives results differing very much one with another and not always agreeing with those of practice — according to the manner of working of the operator.

To remedy this evil Mr. Camerman's assistant, Mr. Nicolas, had designed an apparatus as follows:

It consists (see figure) of a steam generator A with a pressure gauge m and a small safety valve s; further of a superheater B and of a cylindrical vessel C into which the heated steam enters through a pipe T. The lower part C of this vessel ends in a cone c the end of which is provided with a small cock R. The cylindrical part of the vessel C is separated from the conical part by a per-



forated plate P. The upper part is movable and is screwed into the cylindrical body. This movable part bears the steam-supply pipe T and an exhaust-pipe T'. In front of the orifice of the pipe T' is the bulb of a thermometer graduated up to 450°. The steam which escapes by T' is received into the refrigerator D.

The oil is gradually introduced into the apparatus as follows:

It is contained in a receptacle into which a volume determined by the mercury is made to flow through a pipe a. This displaces a volume exactly equal to that of the oil, which is thus driven back drop by drop through a pipe t into the exhaust steam pipe T.

A gas regulator enables the flame of the burner to be maintained constant.

Assume that an oil is to be tested, say for use in a cylinder with superheated steam of 300°. The cock on the pipe t is still closed, and no oil has as yet been introduced; by means of suitable heating arrangements steam at a temperature of 300° is allowed to flow through the vessel C. This temperature once attained, it can, by means of the gas regulator, be maintained very regularly.

The temperature of 300° once permanently established, the cock t is opened and the oil allowed to pass into the steam supply pipe. The oil is carried onward by the flow of the steam and divides itself into two parts. One of the latter is carried by the steam into the refrigerator where the mixture of steam and oil is condensed; this is collected in a graduated syphon tube where the oil is separated from the water by the action of gravity. The second part remains in the cylindrical receptacle, collects in the lower

cone, and can be gradually drawn off by the help of the cock R and caught in a graduated receptacle.

The part which passes through the condenser must, as regards lubrication purposes, be regarded as lost; for in the cylinder of a steam engine it corresponds exactly with that part of the oil which is transformed into the gaseous state by the escaping steam.

To enable the tests made with the same products to give consistent results, and in order that such as are made with different products may admit of comparison one with another, it is of importance that the quantity at steam which passes through the receptacle C within a given time shall always remain the same. The quantity of oil remains the same, because the distributor is entirely independent of the apparatus. In order, however, that the quantity of steam which flows through the receptacle C may remain unaltered, it will suffice that the safety-valve on the steam generator opens at a pressure which is considered to be just sufficient to keep the desired quantity of steam in this vessel. The excess of steam is allowed to exhaust into the air. This safety-valve, if once for all adjusted, must accordingly blow off during the whole duration of the test.

To enable a particular temperature to be attained, it is quite sufficient if the regulator be loaded at the outset with a given weight. Should the temperature corresponding with the weight on the regulator not be attained, this can be due only to the circumstance that the supply of water is not sufficient for the normal working of the apparatus, whether because passages have become choked, or the superheater covered with soot, or any other such eventuality. To set the apparatus going again quickly, it is, therefore, only necessary to clean it. In spite of uniform heating of the normal quantity of steam, the temperature attained in the receptacle C is found to vary. Whether the apparatus is working properly, or not, is very soon noticed. Two litres of water are required for 50 cub. cm. of oil, and the duration of the test is 50 minutes. The maximum error is found to be $1^0/_0$.

After the speaker had answered questions put by Messrs Jacobsen (Copenhagen) and Windfeld-Hansen (Copenhagen) in regard to the apparatus, the Chairman thanked Mr. Camerman for his very interesting communications.

Wood.

Prof. **W. K. Hatt** (Lafayette) laid before the meeting his report:

"Abstract of Report on the Present Status of Timber Tests in the Forest Service, United States Department of Agriculture" (XVI_1).

Prof. Hatt proposed that the Meeting adopt a resulution to the effect that, in making tests on timber, not merely small, selected, test-samples should be examined, but also larger pieces of wood containing defects and structural irregularities such as are usually present in these.

Mr. **E. Camerman** made a number of remarks and moved that the question be entrusted to a committee on timber.

The Chairman, Commander **Münter**, pointed out that the Committee on Timber had been dissolved.

Prof. **A. Martens** approved the idea of tests made with large-sized test-samples proposed by Mr. Hatt, but observed that the expense connected with the carrying out of such tests was in general an obstacle to its realisation.

Prof. **H. I. Hannover** recalled the circumstance that this proposal was negatived at the Congress in Brussels.

Prof. **A. Martens** proposed the following somewhat modified resolution:

> "The Congress recommends the appointment "of a committee on wood testing which has to commu- "nicate with the national societies existing in different "countries. This Committee has especially to examine "into the desirability of making wood tests on larger "pieces containing defects or variations in structural "form instead of limiting the tests to small perfect "pieces."

Prof. **Fuji Tanaka** (Tokio), with regard to the bending tests with wood, called attention to paragraph no. 37 of the method recommended by the IV^th^ Congress for wood testing, which stated that the stresses are to be calculated according to the known bending formula, their values being accepted up to fracture. By the known bending formula was meant $M = {}^1/_6\, fbh^2$ for beams of rectangular section; M bending moment; f, coefficient

of bending strength; b, breadth of beam; h, height of beam. This formula could be used for determining resistance to flexion provided that the stress induced up to fracture is proportional to the strain and "f" constant. The tests however shewed that "f" was not at all constant, but was a function of "h", and increased with a decrease in "h". Tests on Keyaki (Japanese wood) had shown that in beams from 0.5 inch to 7 inches (13 to 178 mm) high, "f" varied between 17,290 and 8,750 lbs. per square inch, (1,210 to 615 kilogrammes per square centimetre). If "f" were taken as constant, the factor of safety introduced might in certain circumstances be a very low one, thus introducing a moment of risk.

If rectangular beams were considered, the speaker recommended, on the basis of his investigations, a new formula $M = \frac{1}{6} f^1 b h^n$. He had conducted a complete series of experiments with a large number of Japanese kinds of wood and had studied published data on several European and American kinds, and he had determined for each kind the respective values of "f^1" and "n"; he handed to the Chairman several tables and diagrams. He added that the conditions of moisture had not been taken into consideration in the tests; he, however, proposed a series of values for use in every day practice, from which the following few have been taken:

Kind of wood	n	f^1 lbs. per sq. inch	h inches
Oak	1.88	8,900	1,11—10,9
Fir from the Vosges	1.80	9,100	1,11—12,8
Fir from Memel	1.83	10.500	1,0 —12,0
American spruce	1.62	11,000	2,0 —13,5

In scientific researches, the speaker added, the result had of course, to be reduced to a given normal degree of moisture and to a given average specific gravity, in order to arrive at the exact values for "f^1" and "n".

He, therefore, recommended that the resistance to flexion of wood of rectangular section should be calculated according to the

formula $M = \frac{1}{6} f^1 bh^n$, and he expressed the hope that future bending tests would be carried out with a view to find out values for "f^1" and "n". The result could then lead to a modification of § 37 for wood tests.

The Chairman thanked the speaker for his interesting communication and propositions.

Mr. **Cl. Segré** (Rome), who was unable to attend the discussion of the Section, presented (by proxy) a treatise on the testing of timber by the Italian State Railways.

Third Day of Meeting, Friday, September 10th, 1909.

Commander B. **Münter** opened the meeting and called on Prof. S. Rejtő (Budapest) to open the proceedings.

Prof. **S. Rejtő** (Budapest) referred to his report and observed that, in the testing of paper, attention is paid to the length of fracture and to the percentage of elongation, instead of to high degrees of resistance. These two data, however, gave no clear picture of the qualities necessary in a paper. Crumpling in the hand had accordingly been resorted to, a method which had now taken the place of bending tests made with the Schopper-machine.

In order to determine the connection existing between the number of the foldings and the quality of the paper, he had first examined the effect of repeated applications of force in the longitudinal direction, and found that in this case the number of repetitions depends on the tenacity as cardinal number, which characterised the proportion borne by the tensile strength to the tension produced by the force applied.

Finally, the speaker had calculated the stress which is set up in the surface fibres during the foldings made in the Schopper machine. It had transpired that, for papers the thicknesses of which lie between 0.04 and 0.11, the proportion borne by the tensile strength to the tension produced by the force applied was constant.

For these reasons the choice of the number of repetitions in the Schopper machine depend only on the sum of the toughness and elasticity as cardinal number, the exponent of which was con-

stant. As soon as the internal work, which was illustrated by a diagram, is known, it becomes possible to calculate the number of the foldings. In all cases in which the Schopper machine cannot be applied, it would be preferable to take the internal work also into consideration.

Prof. **Hinrichsen** (Gr.-Lichterfelde) suggested that the Association also take the testing of ink into its programme. Ink had been subjected to test for some time in America and also in Denmark and tests of this kind had now been begun in Gr.-Lichterfelde also.

Caoutchouc (XV_2).

Report on the

"Contribution to the Question of the Mechanical Testing of Soft Rubber" by K. Memmler and A. Schob (XV_2).

Prof. **E. Heyn** (Gr.-Lichterfelde) presented a report on the tests made at Gr.-Lichterfelde, on the strength of soft rubber. These tests were made with bars as well as with rings, and Prof. Heyn called attention to the instructive collection of fractured test-samples exhibited in the hall. Prof. Heyn moreover referred to a printed report which had been distributed to those present, and directed attention to various difficulties which attended the conduct of the tests, especially of those with bar-shaped samples-amongst others, including the fixing of the test-samples. Prof. Heyn, accordingly, recommended the ring-test as the more reliable, and as easier to make.

Prof. **H. I. Hannover** (Copenhagen) asked whether the cutting out of the samples did not present difficulties, because the knives easily become blunt and the samples thereby become damaged.

Prof. **E. Heyn** observed that difficulties were formerly experienced in the cutting out of the test samples, but that these had now been removed.

Prof. **A. Martens** (Gr.-Lichterfelde) was in agreement with Prof. Hannover in regard to the circumstance that a slight defect produced in the rubber by the knife exercised great influence on the result, and that the cutting out therefore required the greatest possible care. This of course bore reference both to the bars and

to the rings. In order to make sure, every single piece was measured afresh and compared with a template. Since in the cutting out of the test samples, the practice had been instituted of using a cardboard bed, the knives have lasted much better.

Mr. **A. Jacobsen** (Copenhagen) pointed out that a rubber which had shown its excellence in the analysis, might behave badly enough in actual practice. The cause of this always is that the rubber has not been properly vulcanised. He had designed a small apparatus, for the purpose of determining by test, whether a rubber had sufficient elasticity, or whether it was plastic, a circumstance that was always due to insufficient vulcanisation.

The apparatus consists of a pair of pointed tongs ending in hemispheres. By means of a spiral spring the hemispheres are pressed heavily against the very small rubber sample. The samples consist of small discs of about 5 mm. in thickness. If the whole apparatus be heated in a drying chest or in an autoclave, the balls make a smaller or greater permanent impression in the rubber samples, according as elasticity of the latter is greater or smaller.

The main advantage of this apparatus consists in the circumstance that only very small pieces of rubber have to be made use of, and that the heating itself may, even under a considerable pressure of steam, be easily effected. Mr. Jacobsen believe that the apparatus is very suitable for manufacturers' laboratories; at all events he had obtained good results with it.

In practice it is quite impossible to cut out large regular pieces from objects that are to be tested.

Prof **A. Martens** observed in reference to this that the apparatus mentioned by Mr. Jacobsen was in itself worthy of attention, but that laboratories were obliged to employ other methods of testing in order to obtain exact figures and to enable the results obtained at different testing centres to be compared.

The subjects on the programme having all been dealt with, the Chairman, Commander **Münter**, declared the proceedings closed, and thanked those present for the lively interest they had taken in the discussions, and for the valuable contributions, which had helped the solution of the questions under consideration. Com-

mander Münter thanked the secretaries for their excellent work and closed with the words:

"You will certainly agree with me, Gentlemen, when I say that we have spent a few highly interesting hours, and that we have been present at a meeting which can well be termed a feast of intelligence."

Mr. **E. Camerman** here rose to give expression to the thanks of the Meeting to the Chairman for the masterly way in which he had conducted the proceedings. This met with the lively approbation of the Meeting.

Second General Meeting. Saturday September 11th.

Held in the large Festive Room at the Townhall.

Meeting opened at 10 a. m.

President Mr. Foss, opened the sitting by saying that he had addressed, in the name of members of the Congress to His Royal Highness the Crown Prince at Lyngby, the following telegramme:

"The Fifth Congress for the Testing of Materials has the "Honour to give Your Royal Highness their most sincere "thanks for the distinction you have conferred on the Congress "by undertaking to be its Honorary President, also for the "interest you have extended to the work of the Congress, as "expressed by Your Royal Highness at the opening meeting. "(Signed) The President of Congress: Alex. Foss."

The following reply was handed in:

"Lyngby, September 12th 1909. Engineer Foss. I beg you "to give the Members of Congress my heartiest thanks and "salutations. I hope that besides business results, they will carry "away with them also good recollections of their stay in "Denmark. Crown Prince Christian." (Cheers.)

President Foss, stated that by reason of the publication of a journal by the Association, an alteration in the Rules was called for and he put forward the following motion for approval:

"Since the 'Baumaterialienkunde' has ceased to "appear, since also the Council send the Proceedings "gratis to every member, the reference in Paragraph 6 "of the Rules: 'Against payment of the price agreed upon' "is to be struck out, together with the footnote." (Approved.)

The President further added that the present income of the Association was no longer sufficient to place it in a satisfactory

financial position for enabling it to meet its increased activity which was evidenced more particularly by the publication of the Proceedings in the three languages. The Council, therefore, had taken upon themselves, as the Rules enabled them so to do, to raise each **member's contribution from 7·50 to 10 francs,** as from January 1st 1910. Seeing, however, that this increase, even by working on lines of the strictest economy, would not suffice to meet the heavy outlays incumbent upon the Association, the Council had seen fit to put the following motion, the approval of which was asked for:

In consideration of the great importance of the work of the International Association for Testing Materials for the public security, and in consideration of the necessity to make their work as widely known as possible and to place the finances of the Association upon a more satisfactory basis, the Congress decides to authorise the Council to call the attention of governments, public bodies and scientific and industrial undertakings to the work of the International Association hoping to induce them to manifest their interest therein by giving financial support.

The resolution was heartily approved.

Hereupon the President asked the Chairmen of the three sections to communicate to the Congress the motions passed in each Section.

Director O. Busse, Chairman of Section A, put the following resolutions before the meeting and asked for their approval. The resolutions were read one after the other and were approved.

Metals.

Metallography.

In pursuance of the communication of Mr. Rosenhain in which is emphasised the importance of the question of slag enclosures in metallurgical products the Congress recommends the appointment of a Commission for the purpose of studying methods for determining the enclosures, their influence upon the mechanical properties of metallurgical products and for the study of this question in the whole.

Hardness Tests.

The Congress requests the Council to arrange that the next congress, in conjunction with the problem of the determination of hardness by ball or cone pressure-tests, receive reports on uniform tests for the resistance of materials to mechanical wear, and that the council consider the advisability of referring the problem to a committee.

Impact Tests.

A. In order to facilitate the comparison of results of impact bending tests on notched bars the Congress recommends the observation of the following rules, unless circumstances prevent.

1. The notched bar impact test permits the determination of the specific work of rupture or resilience referred to the sq. centimetre of the notched section.

2. a) The bars cut to sufficient length have the following dimensions: $30 \times 30 \times 160$ mm. They are notched to a depth of 15 mm. The bottom of the notch bar is cylindrical of 2 mm radius.

b) For rolled materials such as plates, the bars have the same thickness as the plate, the skin being preserved, and a width of 30 mm. They are notched to a depth of 15 mm. The notch is perpendicular to the surface of rolling and has a cylindrical bottom of a radius of 2 mm.

c) For pieces which do not permit the use of bars 30×30 mm in section the bars are 10×10 mm. They are notched to a depth of 5 mm. The bottom of the notch is cylindrical with a radius of $^2/_3$ mm.

d) The size of the bars used is always to be recorded.

3. In the combined bending and impact tests the impact of the tup is applied at the centre of the bar on the opposite side to the notch, the tup having a knife edge, rounded to a radius of 2 mm. They rest on knife edges spaced 120 mm apart in the case of types a) and b) and 40 mm in the case of type c).

4. The rupture of the bar shall be effected by a single blow by means of an apparatus which enables the work done in fracture to be measured.

5. The temperature should be as nearly as possible between 15 and 25 degrees C. and shall, in all cases, be noted with the results of the tests.

B. The Congress recommends that a Committee be appointed to collate all the results which permit the establishment of relations between the properties, brought out by the tests, and the behaviour of the pieces in service, and that this committee also study the comparison of the various apparatus.

Alternating Stresses.

The Congress takes note of the reports presented, with best thanks to the authors.

Cast Iron.

The Congress recommends to refer the problem of methods for testing cast iron (dealt with by Committee 25) to Committee I.

Influence of high Temperature on Mechanical Qualities of Metals.

The Congress takes note of the excellent report by Professor Rudeloff and warmly thanks him for it.

Electric and Magnetic Properties in Testing Metals.

The Congress recommends the nomination of a committee for studying the use of the electric and magnetic properties of metals in testing metals.

International Specifications for Iron and Steel.

The Vth International Congress welcomes the work of Sub-Committee Ia, approves in general of the principles laid down in Congress report $VIII_1$, and resolves: Committee I and Sub-Committee Ia, are invited to continue their valuable labours in co-operation with the National Societies and, if possible, to lay before the VIth Congress definite proposals as to the basis of International specifications for iron and steel.

Pig Iron.

For the purpose of defining more accurately the quality of Pig Iron than is possible by the present method of grading by fracture appearance, the Congress recommends that Committee I (Sub-Committee Ia) be instructed to inquire in the various countries

concerned as to how far specification on analysis may be usefully substituted for the present method of grading by fracture appearance and that they be authorised to take such steps as they may deem advisable to give effect to this resolution.

Nomenclature of Iron and Steel.

The Congress takes note of the report of Committee 24 upon Nomenclature of iron and steel and expresses their warmest thanks to this Committee for their work. They recommend that the committee remain in function and that they prepare for the next congress a revision of their proposals for uniform nomenclature taking account of the further progress in metallurgy and of any suggestion which may be received from the National Societies for Testing Materials. The Congress approves of the list presented by Prof. H. Le Chatelier, of definitions of the constituents of steel.

Specifications for Copper.

The Congress expresses its best thanks for the work of the Committee on Copper and approves of the proposal of the Committee to extend the scope of their work so as to include the study of specifications for copper alloys.

Standards for Wrought Iron Pipes.

The Congress takes note with thanks of the valuable report of Mr. Karsten on the specifications for wrought Iron Pipes and refers it to Committee I for examination and for reporting to the next Congress excluding the thread question.

Captain Grut, Chairman of Section B, read the following resolutions for acceptance; they were approved.

Before reading the resolution on the constancy of volume of cements Captain Grut remarked that this resolution had been approved in the section with the reservation of the members from Germany. He further stated that the point referred to in the resolution on normal sand would be dealt with by Committee 42:

Cement, Stones, Concrete.

Reinforced Concrete.

The Congress thanks Committee 41 for the work already done, invites it to proceed upon the lines described by Professor

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Schüle, and expresses the wish that the Committee be financially supported by interested institutions and authorities.

Testing Cements by Prisms.

The Congress thanks Committee 42 for the work already performed and recommends it to continue its investigations on the same lines with due regard to the results obtained by the Hungarian committee, to which the Congress expresses its warmest thanks. The Congress expects that the Committee will be able to lay before the next congress proposals for a definite method of using plastic mortars for the testing of cement.

Constancy of Volume.

The Congress decides to recommend the method of Le Chatelier as the standard accelerated test for the constancy of volume of cements[1]).

Accelerated Test of the Strength of Cements.

The results of the numerous hot-water tests are so contradictory, that this test appears too unreliable to admit of its being employed for rapid tests made in order to determine the strength of hydraulic cements.

Under these circumstances, the Congress does not recommend further to pursue the question of the applicability of the hot-water test for rapid tests of the strength of hydraulic cements.

On the other hand the experiments of Mr. Deval have once more demonstrated, how valuable this test may be with regard to the constancy of volume.

Finest Particles in Cement.

The Congress begs Committee 30 to continue its work on the adopted lines and to report the results to the next Congress.

Methods recommended by the IVth Congress.

The Congress modifies § 3. c concerning the methods recommended at the Brussels Congress for cement to run as follows:

[1]) Adopted with the reservation of the members from Germany.

A conical ring, 7,5 cm in diameter at the base, 8,5 cm at the top and 4 cm deep, placed on a glass plate, is quick filled with the paste, and the excess is struck off with the trowel, pressure on the paste and agitation being avoided.

Gypsum.

The Congress resolves to leave the question of specification for Gypsum to the next congress.

Puzzolana.

The Congress leaves the question of the testing of Puzzolanas to the next congress.

Standard Sand.

A Committee is appointed to investigate, whether or not an international standard sand be possible, and if not to secure information showing the comparative value of the different national standard sands[1]).

Cement in Sea Water.

The Congress recommends the appointment of a small committee:

a) in order to obtain by December 1910 any additional information or supplements to the reports presented at the Congress of Copenhagen, they may require,

b) to summarise these reports and supplements and to present the summary of the results in a brief form to the next congress,

c) to collect information on the effect of seawater on structures of more than 25 years' standing, made of Portland cement,

d) to arrange for certain tests (as proposed by Mr. Leduc) on the effect of seawater on specially prepared cement.

Weathering of Building Stones.

A committee is to be formed for the purpose of investigating the influence of the composition of the mortar and the quality of the building stone on the weathering of the masonry.

1) Committee 42 is entrusted with studying this matter.

Commander Münter, Chairman of Section C, put the following resolutions of section C; these were approved:

Sundries.

Wood.

The Congress recommends the appointment of a committee on wood testing which is to communicate with the national societies existing in different countries. This committee is especially to examine the desirability of making wood tests on larger pieces containing defects or variations in structural form instead of limiting the tests to small perfect pieces.

Paints.

(Proposal by Mr. Dechamps.)

The question of galvanisation not having been studied yet in the reports, the Congress desires that researches be made concerning galvanisation, Tinning included.

(Proposal by Mr. Münter).

The Congress considers it highly desirable that special attention be given to the question of keeping the bottom of iron and steel ships clean and requests the Council to have this most important question investigated.

President Foss, then asked the auditors to report upon the accounts.

Mr. Bienfait read the following report:

"The undersigned auditors have compared the expenditure and receipts of the Association for the period "from January 1st 1906 to December 31st 1908 with the "books of the Central Office; they have also examined "these books for the further period up to September 1st "1909, and have found everything correct. The cash in "hand at the Central Office on September 1st 1909 "amounted to 3952·30 crowns which, according to the "statement of the Allgemeine Depositenbank, Wien, was "lying at that Bank. The auditors ask the President for "their discharge and move a vote of thanks to the General "Secretary for his careful administration."

Signed:

Bienfait, Granfelt, Lund.

(The motion was approved.)

The President then brought forward the question of selecting the place and date for the next Congress and informed the Meeting that two invitations had been received. The American Society for Testing Materials through its Chairman. Mr. Ch. B. Dudley, had extended an invitation for the VIth Congress of 1912 and the Russian Government, through H. E. Dr. Belelubsky, had invited the Association for the VIIth Congress. The Council had dealt with both invitations and had met the feelings of the Congress by having already expressed their warmest thanks for both the said invitations. The President then put the following motion before the Meeting.

The Congress decides to hold the VIth Congress of the invitation of the American Society for Testing Materials in the United States of America in Autumn 1912.

(Enthousiastic applause.)

The Congress accepts with warm thanks the invitation of the Russian Government presented by His Exc. Prof. Belelubsky to hold the VIIth Congress in St. Petersburg.

(cheers, applause.)

President Foss noted with pleasure the unanimity and the cheers with which both motions had been approved and especially the cordiality with which the invitation from the American Society for the next Congress had been received. It was true that many Members would find it difficult to spare the time for such a long journey, but no one would fail to recognise the great importance which attached to the close collaboration of the American and the European scientific world for achieving complete accord in interests and in scientific problems. The friendly invitation of the American Society afforded a proof that the American Members were animated with the desire to come into closer contact with the European Members. He (the President) believed, therefore that he would express the wish of all present by coupling to the unanimous acceptance of the American invitation this highly gratifying proof which had been afforded of a closer communion between the two parts of the world. (Hear, hear and cheers.)

Thereupon the President put before the Meeting the motion to the effect that Dr. Ch. B. Dudley, Chairman of the American Society for Testing Materials and a highly esteemed American Chemist be appointed President of the Association.

(Enthusiastic applause.)

President Foss, then addressing Dr. Dudley, said: "You see now, dear Mr. Dudley, the friendliness with which your nomination has been received."

Dr. Ch. B. Dudley: "Gentlemen! Pardon, that I speak now only in English, before the next Congress I hope to do better. I thank you from the bottom of my heart for this great honor. I have spent my life in testing, and now as I approach the end of my work, you have conferred on me the Presidency of this international body of testing engineers, which I cannot but regard as the greatest honor that has ever come to me.

With regard to the next Congress, I will only say now that we shall do our best to make it a success, and if we succeed as well as our Danish friends have done, under the leadership of our President who is just leaving us, I am sure you will be more than satisfied." (Enthousiastic applause.)

His Exc. Dr. N. Belelubsky thanked the meeting for the cordiality with which the invitation to the VII^th Congress in St. Petersburg had been accepted. The Representatives of the Russian Government and the other Russian members of the International Association hoped and wished that this invitation should be followed with complete success, and he assured the meeting that their Russian colleagues would do their utmost to arrange the programme and the preparatory work so as to have a thoroughly satisfactory Congress. (Cheers.)

President Foss then read the following letter which had just been handed to him, and which was addressed by the American Ambassador in Copenhagen, to Mr. W. R. Webster:

"Dear Sir, Referring to our to-day's conversation, I beg to "inform the President of the International Association of Testing "Materials that if it is decided to hold the next Congress in the "United States, it will give me much pleasure to inform my "Government immediately of the fact and to ask them that they "facilitate matters as much as possible so that members may find "their visit both interesting and profitable.

Yours truly,

Signed: *Maurice Francis Egan,*

Ambassador."

(Cheers.)

The President then gave the names of the Members of Council. He stated the very great loss the Association had sustained by the decease of the Council Member for Great Britain, Mr. Bennett H. Brough, who by his very great activity had so much furthered the cause of the Association in that Country. He asked the Members to stand in their place to show the deep regret that was felt at his death. (The members rose and stood for a moment in solemn silence). Mr. G. C. Lloyd, Secretary of the Iron and Steel Institute, had been appointed upon the Council by the British Members and the President gave him a cordial welcome.

Ministerialrat C. von Banovits, Hungary, after many years of valuable service for the Association had been compelled, by reasons of health, to relinquish his post on the Council. Hofrat Professor A. Rejtő had been appointed in his stead. The provisional appointment of Director J. O. Roos af Hjelmsäter who acted for Mr. G. Dillner, the latter's time being fully taken up — had been made final, Mr. Roos having been voted unanimously on the Council. The President also cordially welcomed these two Gentlemen. The new list therefore was as follows:

Permanent Member of Council:

Dr. techn. *Franz Berger,* k. k. Sektionschef im Ministerium für öffentliche Arbeiten, Stadtbaudirektor a. D., Vienna.

Elected Members of Council:

Belgium: Mr. *A. Greiner,* Directeur Général de la Société John Cockerill, Seraing.

Denmark: Mr. *H. I. Hannover,* Professor Royal Technical High School and Director of the Government Testing Laboratory, Copenhagen.

Germany: Dr. Ing. *A. Martens,* Professor, Geh. Ober-Regierungsrat, Mitglied der kgl. Akademie der Wissenschaften zu Berlin, Direktor des kgl. Materialprüfungsamtes, Gr.-Lichterfelde.

France: Mr. *A. Mesnager,* Ingénieur en Chef des Ponts et Chaussées, Directeur des Laboratoires à l'Ecole des Ponts et Chaussées, Paris.

Great Britain: Mr. *G. C. Lloyd,* Secretary to the Iron and Steel Institute, London, S. W.

Holland: Mr. *L. Bienfait,* Engineer, Partner in the Firm Koning and Bienfait, Amsterdamm

Italy: Mr. *J. Benetti,* Ingénieur, Professeur et Directeur de l'Ecole R. d'application pour les Ingénieurs, Bologna.

Norway: Mr. *S. A. Lund,* Section Engineer at the General Management Offices, Norwegian State Railways, Christiania.

Austria: Mr. *B. Kirsch,* k. k. o.-ö. Professor und Vorstand des mech.-techn. Laboratoriums der techn Hochschule, Wien.

Roumania: Mr. *Constantin M. Minoresco,* Inspecteur Général Directeur de l'Ecole des Ponts et Chaussées, Bucarest.

Russia: Dr. Ing. *N. Belelubsky,* Exz., Geh. Rat, Mitglied des Ingenieurrates im kais. Wegebau-Ministerium, em. Prof. Direktor des mechan. Laboratoriums am kais. Institut für Wegebau-Ingenieure in St. Petersburg.

Sweden: Mr. *J. O. Roos af Hjelmsäter,* Director of the Material Testing Laboratory, Royal Technical High School, Stockholm.

Switzerland: Mr. *F. Schüle,* Professor at the Federal Politechnikum, Director of the Federal Testing Laboratory, Zürich.

Spain: Mr. *J. Marvà y Mayer,* General du Génie, Chef de Section au Ministère de la Guerre, de l'Académie Royale des Sciences exactes, physiques et naturelles, Madrid.

Hungary: Hofrat Prof. *A. Rejtő*, Technical High School, Budapest.

United States of America: Dr. *Chas. B. Dudley,* Chemist, Pennsylvania Railroad, Altoona, Pa.

The following Gentlemen have kindly promised to continue to act for the Council in their respective Countries:

Australia: Mr. *W. H. Warren,* M. Inst. C. E., M. Am Soc. C. E, Challis Professor of Engineering, University of Sydney.[1]

Finland: Mr. *A. Granfelt,* Director of the Finland State Railways, Helsingfors.

Luxemburg: Mr. *E. Bian,* Directeur des Usines de Dommeldange et des Forges d'Eich, Dommeldingen.

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[1]) While drawing up this report, the gratifying news was received from Australia to the effect that the necessary number of members (20) giving the right of appointing a member of Council had been exceeded, and that Prof. W. H. Warren, of Sydney University, had now been elected full member of Council.

Portugal: Mr *J. da P. Castanheiro das Neves,* Ingénieur, Directeur des Etudes et Essais des Matériaux de Construction, Lisbon.

Servia: Mr. *M. Milasinovic,* Vice-Director of the Royal Servian State Railways, Belgrade

Dr. **Franz Berger** thought it a pleasant duty to give expression to the warmest thanks of every member present for the way in which the Congress, now coming to a close, had been carried through. They all were most grateful to the Copenhagen Organizing Committee, for the latter had not only thoroughly prepared the ground for the scientific work, but had also included most pleasing and instructive items in the programme. He bore in his mind first of all the Chairmen of the various Sections and the Secretaries, who had been most completely devoted to their work. Before everyone, however, the thanked their retiring President, Mr. Foss (Applause.) The cheers with which the meeting had just received his words, dispensed him from saying more; he would only add that the Council in their last deliberation, held just before the opening of this last meeting, had made use of the rights conferred upon them by the Rules and had conferred upon Mr. Foß the greatest honour that was in their gift. They had appointed him a Permanent Honorary Member of Council. He (the speaker) wished to announce this to the Meeting, and renewed his cordial thanks for all that had been done for them. (Applause.)

Mr. **Greiner** called attention to the most admirable organisation which had governed all items, and to the smoothness with which the business portions of the programme and the excursions and visits had all been carried out. The work that such an organisation required on the part of the Chairmen of Sections and of local Committees could not be overstated. He reminded the members that at the last moment, when everything had been fully prepared, the place for holding the meetings was altered from Parliament House to the Town Hall. He also invited the members to thank the various Chairmen and especially President Foss for the great pains they had taken, and for the remarkable way in which they had managed everything. He also desired to repeat in French the statement which Dr. Berger had made in German, to the effect that the Council had appointed Mr. Foss permanent Honorary Member of Council. (Applause.)

Mr. **Wm. R. Webster** thanked the General Secretary for the great care which he had devoted to his Secretarial duties and especially for his splendid work in regard to the preparation of the Congress papers. (Applause.)

Mr. **G C. Lloyd**, as representative of the British Members, confirmed what had fallen from the previous speakers. The Congress had been a most successful one, he might also say the most successful one that had ever been held. Under the guidance of their President, they had done much good work; they had, besides, spent a most enjoyable time. He added his thanks to those of the other speakers. (Cheers.)

President Foss returned thanks for the kind words that had just been spoken. He hoped all the members would carry away with them a good impression of Copenhagen; he accepted the distinction which had been conferred upon him by the Council, which he considered also as a compliment to his Danish friends who, like him, had done all that lay in their power to achieve success for the Congress. He thought it his duty to state that if this Congress had shown progress, and if matters had turned out more satisfactory than had perhaps been possible on former occasions it was in a large measure due to the new arrangement made, namely, to the publication of the papers. He therefore confirmed what Mr. Webster had said and gave his warmest thanks to the General Secretary for the great care he had devoted to this work. (Applause.)

Mr. **Stead** who was received with cheers handed in his paper to the meeting after President Foss had thanked the Town authorities for their kindness in allowing the use of their magnificent hall.

His paper, which was illustrated by a number of admirably prepared lantern slides, read as follows.

Lecture by Mr. J. E. Stead on microscopy and macroscopy in the workshop and foundry.

After a brief reference to the death of Dr. Sorby, the pioneer of metallography, through which the whole scientific world had sustained a severe loss, Mr. Stead presented the views expressed by a number of British manufacturers on the value of the microscope in investigating metals.

In some copper and brass factories the microscope had proved invaluable. Mr. Tomlinson, manager of the Broughton Copper Company, wrote that indirectly it was useful, because one could with its aid detect in metals certain defects caused, for instance, by overheating, and this damage might be traced to some prior annealing or other heating operation. Cases often arose when the expense and time taken by a chemical analysis had been saved, as the microscope afforded a rapid means of deciding approximately the composition of metals and alloys. The Royal Gun and Carriage Factories, Woolwich, reported that the microscopic examination of brass was a matter of daily routine. The Consett Iron Company, Ltd., stated that the microscope was regularly used in all cases where ordinary analysis failed to yield satisfactory explanation, and more extended research was necessary. According to the report of the Wigan Coal and Iron Company, Ltd., the microscope was regarded in their works as a necessary adjunct to the chemical and metallurgical work in the laboratory. In the Crewe shops of the London and North-Western Railway it was said that it would appear from microscopical investigations that it was possible to discover the qualities of metals even better than by either mechanical tests or chemical analysis, within certain limits Messrs. Thomas Firth & Sons, Ltd., expressed the opinion that before practical everyday use could be made of the microscope, the meaning of the terms and the reactions of the substances they represented must be

learned by practical experiment and observation. Messrs. D. Colville & Sons, Ltd., reported that they found the microscope of very great assistance in everyday work. Messrs. Vickers, Sons & Maxim, Ltd., stated that the microscope was in constant use in connection with the heat treatment of the various alloy steels used in gun and armour-plate manufacture, &c. It had been found to be most useful both as a guide indicating correct heat treatment and as a means of ascertaining whether the treatment ordered had actually been carried out. A metallurgical investigation laboratory had been in active operation for some years at the Sheffield works of the company, and in it the microscope had been very extensively used in researches bearing upon the special classes of steel whose manufacture had presented difficulties.

Messrs. Cammell, Laird & Co., Ltd., stated that, if a casting was to be subjected to subsequent costly machining, or complicated heat treatment, a preliminary micro-examination was sometimes found useful, although even in those cases the examination of a large etched section by means of the hand magnifier was usually more successful. In the great majority of cases the microscope was employed, not to discover defects, but to investigate the origin and determine the particular stage at which they were produced. For the latter purpose microscopic methods were absolutely indispensable.[1])

Those were typical examples of replies received from British manufacturers. There were few large industrial works where microscopic examination was not regarded as essential, and if works had not microscopic equipment they obtained outside professional assistance. In every college and technical institution in Great Britain where metallurgy was taught, students were instructed how to use the microscope for the purpose of obtaining knowledge of the structure of metals and alloys.

He had obtained from many well-known investigators of European and American fame who were interested in the application of the microscope, information of which the following is, a brief summary:

With regard to France Mr. P. Pellin had furnished a list of manufactories, numbering seventy, in which the microscope had

[1]) Messrs. The North Eastern Steel Co., Ltd., and Messrs. The South Durham Steel and Iron & Co., Ltd., have used the microscope with great advantage in checking the heat treatment and mechanical working of steel.

been found to be an assistance to more efficient practice. Mr. Le Chatelier, whose admirable microscope was used throughout France, stated that considerable installations were in use at the works of De Dion-Bouton, under the management of Mr. Guillet; at the works of Saint Jacques at Montluçon, the director of which is Mr. Charpy; and at the steelworks at Creusot, under the management of Mr. Harmet.

Dr. Carl Benedicks stated that in Sweden, up to the present time, the microscope had been mainly used in connection with tool and special steels. Metallography, as a routine science, had not been employed to a great extent. Captain N. Beraieff communicated some very interesting information as to the use of the microscope for very many years by Anossoff, and later by Tschernoff, Rjechotarsky, and at many of the steelworks in Russia.

In Belgium, at the works of the Société Anonyme Fabrique Nationale d'Armes de Guerre and Société Anonyme des Ateliers Germain, the microscope was in regular use. At the first-named works, the Le Chatelier microscope had been an indispensable necessity in the examination of all polishable metals, although for industrial purposes its use could only be said to be limited. La Société des Ateliers Germain reported that the microscope was of special service for the discovery of causes leading to fracture of metals used in motor car construction. In Spain, at the Trubia Gun Factory, the microscope was extensively applied to practical purpose for the examination of ordinary and special steels, alloys, brass, bronzes, &c. It was interesting to note that it had been suggested that in every test of brass for cartridges the micrographical investigations should be adopted.

In America, Mr. Albert Sauveur stated that he had information of the use of the microscope in 134 large industrial concerns, 92 of which were steelworks, 16 non-ferrous metallurgical plants, and 26 miscellaneous industries or concerns, such as railroad companies, &c. The application of the microscope was taught in twenty-eight technical institutions. On the authority of Dr. Wüst, very many works in Germany and other countries used the microscope as an aid to their work.

The method of auto-sulphur printing, first discovered by Prof. Heyn and applied by him and by his assistant, Prof. Bauer, and afterwards modified by Prof. Baumann, if properly applied,

was most useful in foundry practice. This method had been more usually applied for the detection of local and axial segregation of sulphur in steel, but it was capable of showing approximately the amount of sulphur in cast iron. As phosphorus in cast iron existed in isolated masses of phospho-iron eutectic, and as the amount of these masses bore a close relation to the percentage of phosphorus present in pig iron, an approximate estimate of the element actually present might be made by examining polished and etched sections of grey pig irons. It was well known that the amount of combined carbon in steels could be estimated with a fair degree of accuracy by microscopic examination; it was almost as easy to estimate the amount of combined carbon in grey cast iron or in grey pig irons. The importance of this fact to the foundry foreman was very great.

The macro- and micro-structure of steel castings was of great importance to the steel-founder. He could readily locate segregations, and determine whether the sulphur was relatively high or low, by the auto-sulphur printing process. He could check the work done in the annealing furnace, and determine, by the examination of pieces cut out from the casting, whether the annealing temperature had been too high or too low, and whether or not the castings had been annealed.

In foundry practice, where the facings of the moulds consisted of a graphitic mixture, the outer envelope of the steel in contact with the mould itself was usually higher in carbon than the mass of the metal. When the annealing had been properly done, the envelope was completely decarburised, and the castings sheathed in a thin covering of carbonless iron or ferrite. This decarburised layer varied in thickness with the time and temperature, and with the percentage of carbon in the steel. In steels containing about 0·30 % to 0·35 % carbon, it was sometimes only 0·05 mm in thickness when the castings were small, and as much as 1 mm in large castings. In unannealed steels the ferrite envelope was almost invariably absent. The altered microstructure of the mass of steel produced by annealing, as compared with the "casting structure", was usually sufficient to enable one to say whether the steel had been annealed, but not if the temperature of annealing had been excessive, and it was in such cases that the decarburised envelope had to be looked for. A thick ferrite envelope and a coarse granular structure of the pearlite in the steel itself were indicative of annealing

at excessive temperatures. The presence of granular pearlite indicated clear evidence of prolonged annealing at temperatures between 750° C. and 650° C., and steel in this condition was usually very soft. When the annealing was done by heating to between 850° C. and 900° C., and the steel was removed from the furnace and cooled in the air, the pearlite was nearly always of the lamellar variety.

It was now a common practice to improve the surfaces of defective steel castings by electrically melting and filling blowholes with iron or steel. It was recognised in important work that the castings should be annealed after electric welding. Etching with 20% nitric acid after rough polishing would show at once whether electrically welded steel had been annealed or not, for, if not, the steel surrounding the weld always consisted of either martensite, troostite, or sorbite, and each of these gave a dark stain on application of the strong reagent, whilst the iron melted electrically and used to fill the cavities was always in the form of ferrite, and remained white after etching.

This etching method was, therefore, most valuable, for it enabled the works inspector or engineer to determine on the finished work the areas welded, and whether or not the steel had been annealed after welding. Annealing not only changed the troostite, &c., into pearlite, but removed the strains set up by the excessive local heating.

In the manufacture of malleable castings, the microscope was useful in determining to what extent decarburisation had taken place, and whether there was anything abnormal in the structure of the metal. There was no better means of controlling the workmen who were responsible for the proper case-hardening of iron and steel than by the use of the microscope. Sections of case-hardened material after polishing and etching indicated with certainty the depth to which the carbon had penetrated the metal.

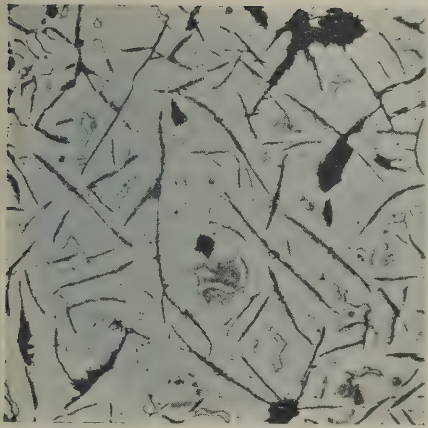
Many so-called mysterious failures of boiler and other structures had been explained by the use of the microscope. In most of them fracture had been proved to have been initiated by maltreatment of the steel when cold. The steel had been found to be crushed, the ferrite grains flattened, and the metal made most tender. In four cases at least of boiler failure maltreatment had been proved to have been the cause. The auto-sulphur prints obtained from sections of steel billets enabled the manufacturer readily to detect serious

segregation, and the same method could be used for detecting segregation in wire rods and even in the finished wire.

The microscopic examination of wires also was useful, and particularly so in the case of wires and wire ropes which had failed during use and in the course of manufacture. It had been noticed that wires which contained definite proportions of fine micro strings of foreign matters, such as cinder, oxides, or sulphide of manganese, were incapable of standing the torsion test, and sometimes broke up during the pickling process after the wire rods had been patented or "tempered".

The microscope was also useful in ascertaining whether or not the rods had been evenly tempered. It occasionally happened that in patenting high carbon rods $0{\cdot}75\%$ to $0{\cdot}95\%$ portions of the steel actually contained free martensite, or, as some called it, hardenite, and when martensite was present, "drawing" was impossible. On polishing longitudinal sections and etching with picric acid in alcohol or other suitable reagent, the martensite remained white on a ground mass of troostite and sorbite.

Sometimes during use, wire ropes employed for winding and for cable tram lines were subjected to violent friction sufficient to heat the crowns of the wires to above the recalescence point, and this, followed by chilling, left the surface skin intensely hard. An examination under the microscope of wire so affected, after suitable etching, revealed the presence of martensite. When the brittle skin was formed, and the rope passed over a pulley in such a way as to produce considerable flexure, the hardened skin cracked, and the cracks once formed travelled through the wires, which then broke up, and the rope became useless for further work and had to be removed.



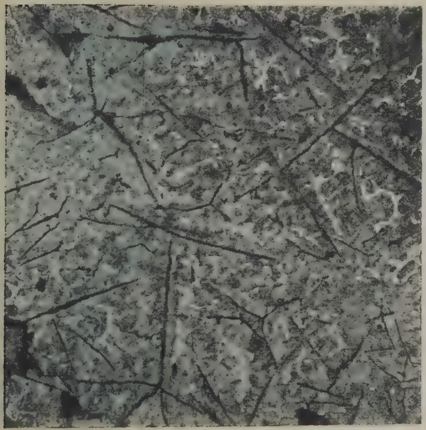
Combined Carbon in Pig Iron.

No. 1. Staffordshire Pig Iron containing 0·05% Combined Carbon. Etched with Picric Acid in Alcohol. x 40.

Combined Carbon in Pig Iron.

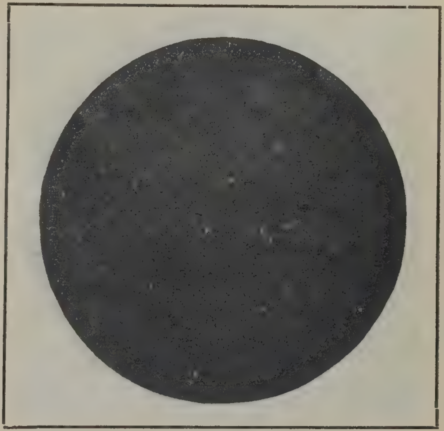
No. 2. Cleveland No. 3. Pig Iron containing 0·3% Combined Carbon. x 40.

The half tones in Nos. 1, 2, and 3 represent Pearlite.



Combined Carbon in Pig Iron.

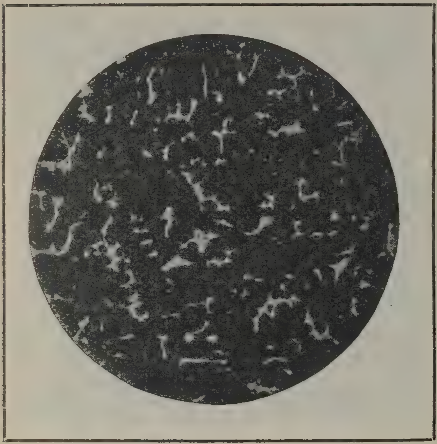
No. 3. Lincolnshire No. 3. Pig Iron containing 0·7% Combined Carbon. x 40.



Phosphorus in Pig Iron.

No. 4. Hematite Pig Iron with 0·04% Phosphorus, strongly etched with 1 20 Sp. Gr. Nitric Acid. x 50.

The white parts represent the Iron-Phosphorus eutectic.



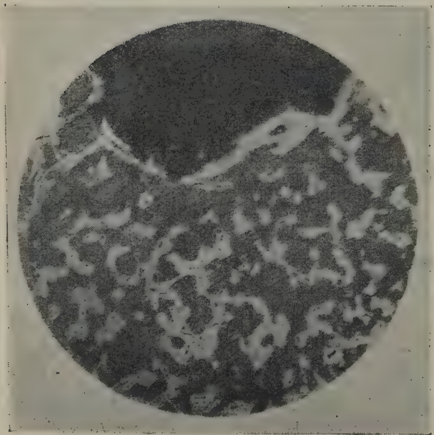
Phosphorus in Pig Iron.

No. 5. Pig Iron with 0·7% Phosphorus. x 50.

Phosphorus in Pig Iron.

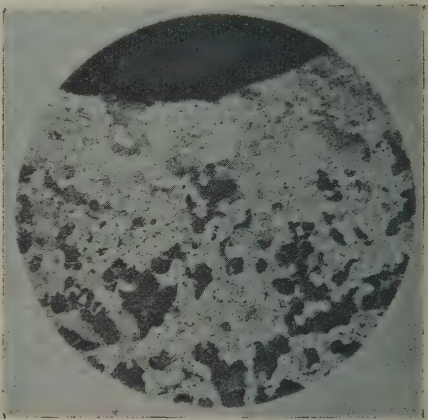
No. 6. Pig Iron with 1·5% Phosphorus. x 50.

The white parts represent the Iron-Phosphorus eutectic.



Steel castings. Proof of annealing.

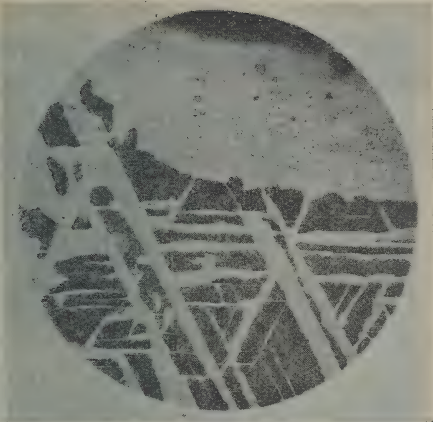
No. 7. Outside skin of a steel casting, unannealed. x 40.



Steel castings. Proof of annealing.

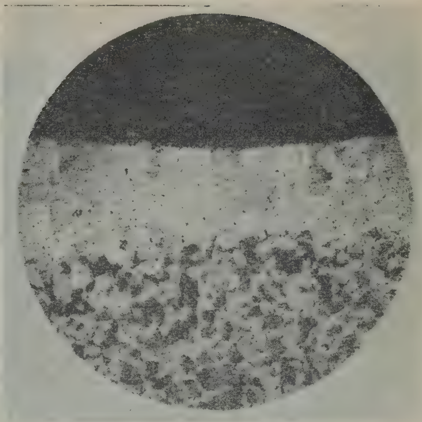
No. 8. Outside skin of a steel casting, well annealed. x 40.

The ferrite envelope usually indicates that the steel has been through the annealing furnace.

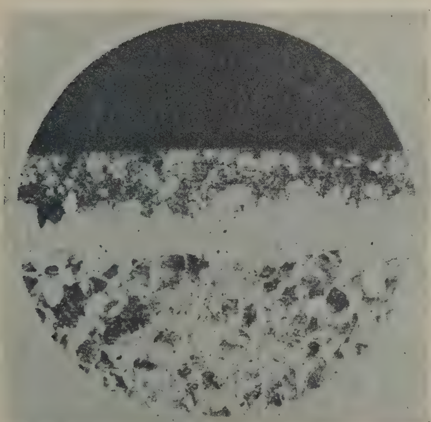


Steel castings. Proof of annealing.
No. 9. Steel casting overheated in the annealing process. x 40.

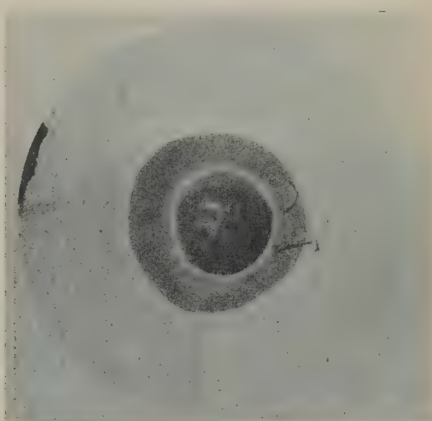
The ferrite envelope usually indicates that the steel has been through the annealing furnace.



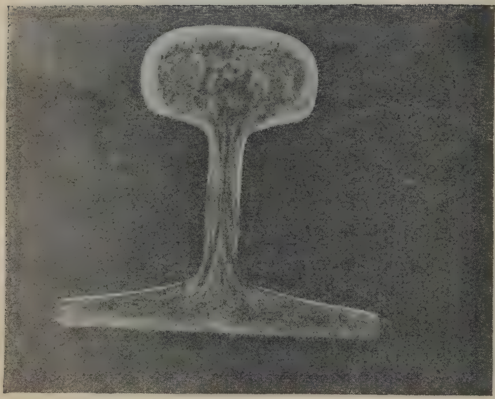
Steel castings. Proof of annealing.
No. 10. Malleable casting, well annealed, capable of being bent. x 40.



Steel castings. Proof of annealing.
No. 11. Malleable casting, annealed but recarburised on the outside; it would not bend. x 50.



Electric welding of steel.
No. 12. Effect of applying an electric arc to surface of steel rail head for two seconds. The steel contained 0·7% Carbon. It was polished and etched with nitric acid and magnified 2·25 diameters. The central dark part represents a cavity; the white ring round this is decarburised steel, or ferrite. The dark ring is hardened steel. This dark ring indicates that the steel had not been annealed after the electric welding.



Macro-structure showing difference in structure of rails rolled from top, middle, and bottom of ingots.

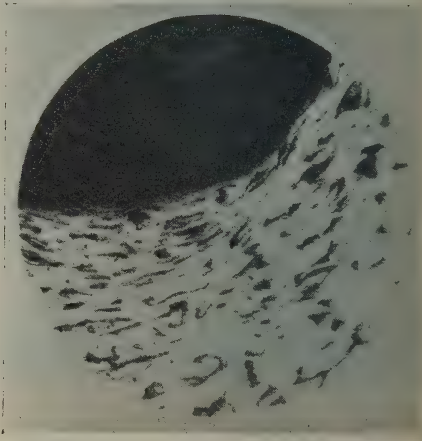
No. 13. Rail rolled from top of ingot.

Macro-structure showing difference in structure of rails rolled from top, middle, and bottom of ingots.

No. 14. Rail rolled from middle of ingot.

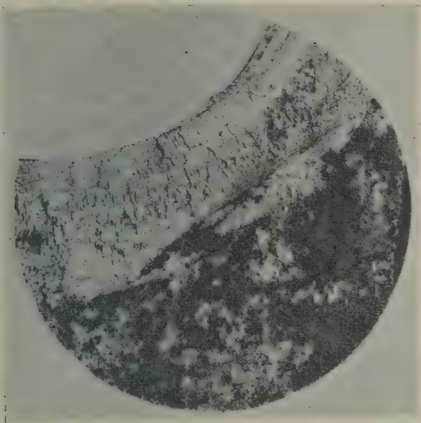
Macro-structure showing difference in structure of rails rolled from top, middle, and bottom of ingots.

No. 15. Rail rolled from bottom of ingot.



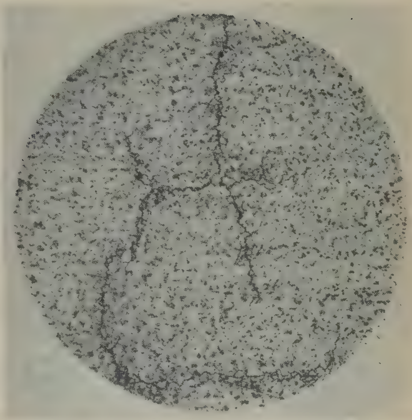
Structure of cold crushed steel.

No. 16. Structural steel crushed by caulking. x 40.



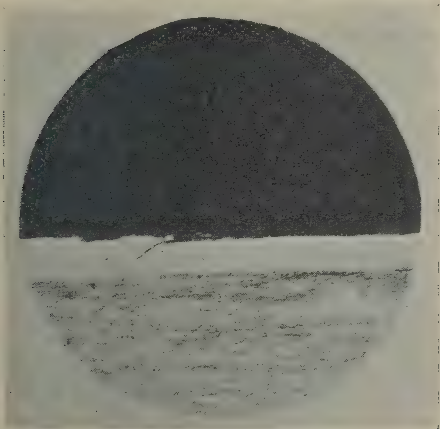
Structure of cold crushed steel.

No. 17. Crushed surface of steel in screw bolt hole in firebox of boiler after long use. Cracks developen at the crushed surfaces and led to extended fracture. x 40.



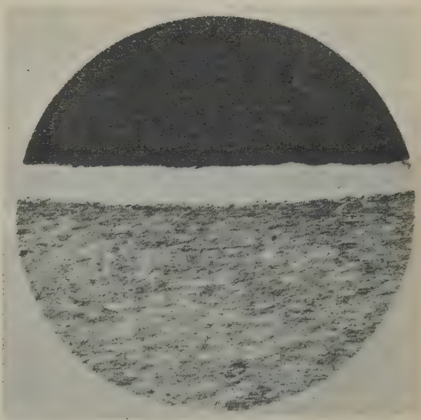
Structure of cold crushed steel.

No. 18. A growing fatigue fracture in a steel marine boiler, due to excessive strain. x 40.



Hard skin on wire of rope, produced by excessive friction.

No. 19. Longitudinal section through the crown wire of a steel hauling rope, showing hardened skin produced by excessive friction and fracture through the skin, etched with Picric Acid. x 40.

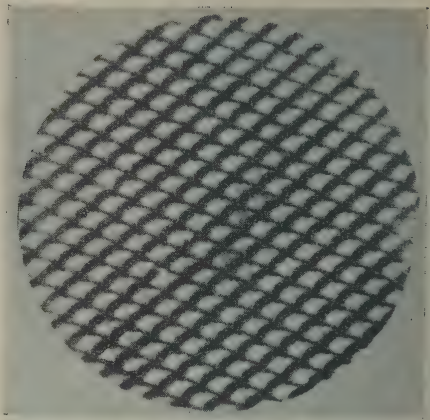


Hard skin on wire of rope, produced by excessive friction.

No. 20. Same as the foregoing at a part where fracture had not occurred. x 40.

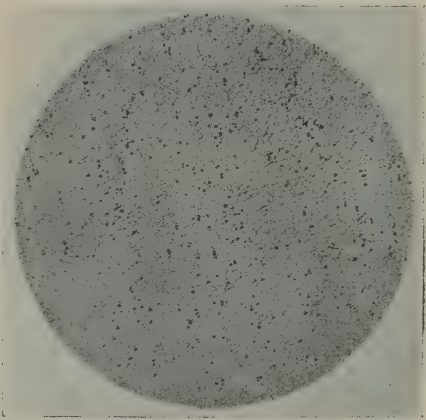
Hard skin on wire of rope, produced by excessive friction.

No. 21. Same as the foregoing after attempting to bend, showing fracture through the hard skin.



Miscellaneous.

No. 22. Surface of cross cut file after grinding off the teeth until a perfectly flat surface was obtained, then etched with Picric Acid. It shows that the base of the teeth are the hardest portions. x 40.

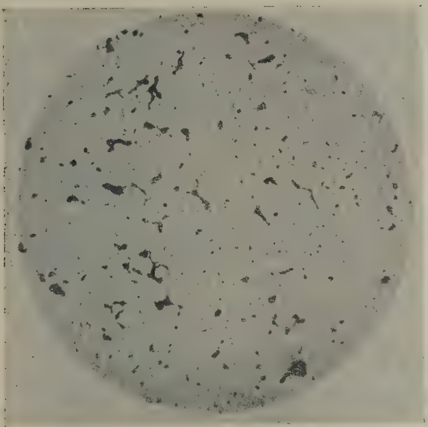


Miscellaneous.

No. 23. Longitudinal section of a hard steel wire rod after patenting, which broke to pieces when placed in the pickling bath. Polished only. x 40.

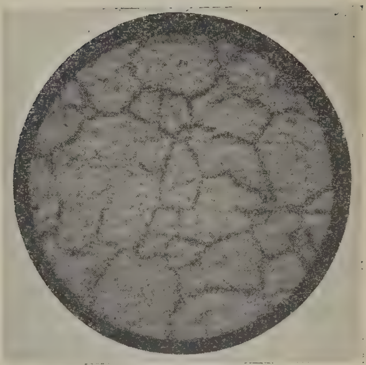
Miscellaneous.

No. 24. Section through a lap in a steel rail head, showing that the borders of the lap are partially decarburised. x 40.



Miscellaneous.

No. 25. Polished section of a brittle bronze gear wheel showing slag inclusions. x 40.



Miscellaneous.

No. 26. Section of the outside of a copper plate which had been heated in a reducing gas. The copper plate became quite brittle and revealed the peculiar structure shown. Photograph supplied by Mr. Tomlinson of Messrs. The Broughton Copper Co. Ld. Manchester.

VOLUME I.

Subject Index.

The Arabian letters, large type, (e. g. **5**) mark the Number of the "Proceedings". The Roman figures with small additional numbers (e. g. III_2) refer to the particular Congress Report.

Steel.

Stones.

Strains.

Technological Mechanics.

Tenacity.

Testing. (See also Tests.)

Tests. (See also Testing.)

Author Index.

The Arabian letters, large type, (e. g. **5**) mark the Number of the "Proceedings". The Roman figures with small additional numbers (e. g. III_2) refer to the particular Congress Report.

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